

4.2 Potential Outcomes

This section describes the safety and health accomplishments anticipated over the next five years for each strategic goal of the Mining Research Plan. The section begins with a list of the seven strategic goals and the future strategic program outcomes expected to be produced as the research results for each goal are implemented. Listed within each goal are a number of potential intermediate outcomes that support the future strategic program outcomes. These potential intermediate outcomes are expected if currently active research projects are concluded successfully, and the results are implemented by the intended customers. On the subsequent pages, for each potential intermediate outcome, there is a brief description of the problem, research approach, intermediate outcome expected from the research, and a list of past and planned outputs, which will contribute to the potential outcome. Both past and planned outputs are included since these research projects are in progress.

Strategic Goal 1 - Respiratory diseases: Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.

Future Strategic Program Outcomes: Within 10 years, reduce the respirable coal dust overexposures of operators of longwall and continuous mining machines, roofbolters, and surface drills by 50% and the overall silica exposure of crusher operators and stone cutters by 50%. Within 10 years, reduce coal miner exposure to DPM by 80% and metal nonmetal miners DPM overexposure rates by 50%.

Potential Intermediate Outcomes:

1. Canopy Air Curtain
2. Methane Control Handbook
3. Control Technology for Coal Worker Pneumoconiosis (CWP) Hotspots
4. Measuring Diesel Particulate Matter with Diesel Detective Monitoring Technology
5. Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines
6. Diesel Particulate Filter Selection Guide
7. Cooperative NIOSH/IMA-NA Dust Control Handbook for Mineral Processing Plants
8. Inline Series Spray Scrubber
9. Evaluation of a Continuously Regenerating Diesel Exhaust Trap with Nitrogen Dioxide Control
10. Longwall Dust Surveys
11. Filter Materials for Silica Analysis When Using the Personal Dust Monitor
12. Facilitating the Use of Personal Dust Monitors as a Means of preventing Coal Workers' Pneumoconiosis
13. Assessing the Performance of a Heat Exchanger to Reduce Outby Diesel Exhaust Temperatures
14. Dust Capture and Induced Airflow of Various Spray Nozzle Designs
15. Open Structure Design
16. Hydrogen-Powered Mine Vehicle Reduces Miner Exposure to Diesel Emissions

Strategic Goal 2 - Hearing loss: Reduce noise-induced hearing loss (NIHL) in the mining industry.

Future Strategic Program Outcomes: Reduce the frequency of noise overexposure of miners by 25% in 5 years and 50% in 10 years.

Potential Intermediate Outcomes:

1. Underground Metal Noise Control Guide
2. Improved Hearing Protection
3. A Health Hazard Study of Surface Drilling Operations
4. Model Hearing Loss Prevention Program
5. Engineering Noise Controls for Roof Bolting Machines
6. Engineering Noise Controls for Continuous Mining Machines - Jacketed Tail Roller
7. Engineering Noise Controls for Horizontal Vibrating Screens
8. Administrative Computer Program
9. Engineering Noise Controls for Continuous Mining Machines - Dust Collector Fan

Strategic Goal 3 - Cumulative injuries: Reduce repetitive/cumulative musculoskeletal injuries in mine workers.

Future Strategic Program Outcomes: Reduce repetitive/cumulative musculoskeletal injuries by 35% based on the 2003 repetitive/cumulative musculoskeletal injury rate.

Potential Intermediate Outcomes:

1. Improving Mobile Equipment Operator Ergonomics
2. Age Awareness Training Modules
3. Slips and Falls Research
4. Knee Injury Prevention
5. Improved Risk Assessment for Low Back Disorders in Mining
6. Ergonomic Processes Implementation/Integration and Process Metric
7. Redesign of Dragline Workstations
8. Reducing Injuries during Bagging Tasks
9. Reducing Injuries Due to Railcar Loading and Maintenance Activities
10. MSD Prevention and Intervention Education Modules

Strategic Goal 4 - Traumatic injuries: Reduce traumatic injuries in the mining workplace.

Future Strategic Program Outcomes: By 2014, reduce traumatic injuries by 35% based on the 2003 traumatic injury rate.

Potential Intermediate Outcomes:

1. Guidelines for Improving Ore Pass Safety
2. Forklift Operating Warning System (FLOWS)
3. High-Voltage Continuous Mining Machines
4. Power Line Proximity Warning Alarms
5. Electrical Arc Burns
6. Roof Bolter Health and Safety Guidelines
7. Reducing Blast Area Security and Flyrock - Related Injuries and Fatalities in Mining
8. Remotely-Controlled Bulldozer on Coal Stockpiles

Strategic Goal 5 - Mine disasters: Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the effectiveness of, emergency responders.

Future Strategic Program Outcomes: Reduce the number of injuries and deaths attributed to mine fires, explosions, inundations, and rescue and response activities by 25% between 2010 and 2014 compared to the average yearly total from 1990-2001 as compiled from MSHA accident statistics.

Potential Intermediate Outcomes:

1. Advanced Methane Control in Underground Coal Mines
2. Reducing Fire Hazards in the Metal-Nonmetal Mining Industry
3. Managing Mine Fires
4. Reducing Fire Hazards in Underground Coal Mines
5. Communications and Decision Making During Mine Emergencies
6. Utilization of Engineered Ventilation Systems in Large Opening Mines
7. Remote Construction of Seals for Fire Control and Abatement
8. Prevention of Catastrophic Coal Dust Explosions in Mines

Strategic Goal 6 - Ground control: Reduce ground failure fatalities and injuries in the mining industry.

Future Strategic Program Outcomes: Reduce mine fatalities by ground failures by 50% within 8 years. Reduce injuries by ground and roof support system failures by 25% within 5 years and by 50% within 8 years. Reduce unplanned roof falls by 20% within 5 years and by 40% within 8 years.

Potential Intermediate Outcomes:

1. Improved Highwall Stability to Reduce Surface Mine Hazards
2. Reducing Injuries by Improving Shotcrete Design Criteria
3. Improved Pillar Design in Metal and Industrial Mineral Mines to Reduce Ground Control Hazards
4. Avoiding Inundations: Developing Guidelines for Mining near Bodies of Water
5. Improved Mine Safety through Optimized Extraction
6. Multiple-Seam Mining Design Guidelines
7. Design of Mine Ventilation Stoppings
8. Roof Span and Pillar Layout Guidelines for Stone Mines
9. Reducing Ground Fall Hazards in Coal Mines with Low Strength Roof
10. Highwall Mining Stability Guidelines
11. Increase Roof Fall Forecast Times with Sensor-Based Monitoring Techniques
12. Reducing Ground Fall Hazards in Metal Mines with Weak Rock

Strategic Goal 7 - Surveillance and training: Determine the impact of changing mining conditions, new and emerging technologies, training, and the changing patterns of work on worker health and safety.

Future Strategic Program Outcomes: Over the next 10 years, identify the impacts of changes and make recommendations for mitigating adverse impacts.

Potential Intermediate Outcomes:

1. Improving Miner Safety by Developing Toolbox Training Sets
2. Improving Miner Safety by Developing Interactive Computer Simulation Training
3. Improving the Accuracy of Determining Worker Exposure to Airborne Silver
4. New Miner Training
5. Improved Technology Transfer Via the Web

Potential Intermediate Outcome for Respiratory Diseases

Canopy Air Curtain

Background

The results of MSHA compliance sampling indicate that roof bolter operators are exposed to some of the highest silica dust levels measured in underground coal mines. From 2000 through 2004, MSHA inspectors collected and analyzed over 4000 samples for silica. Of these, 14% exceeded the permissible exposure limit. Past research by NIOSH has found that significant silica exposure can result when a roof bolter must work downwind of a continuous miner. With the increase of continuous miner supersections, bolter operators are being required to work downwind of continuous miners more frequently. Consequently, control technologies are needed that can reduce roof bolter operators' exposures to dust when working in the return airstream of a continuous miner.



Air curtain being tested on roof bolter

NIOSH researchers developed a system that filters approximately 250 ft³/m of ventilation air and transports it through flexible tubing to an air curtain mounted on the underside of an operator's canopy during installation of roof bolts. The air curtain contains baffling material that distributes the clean air evenly down over the operator. Laboratory tests were conducted to evaluate the effectiveness of the air curtain under differing operating conditions. Results showed that the dust levels were reduced under the curtain by approximately 60% for the mean air velocities commonly found in roof bolter entries. An underground evaluation was also completed recently to evaluate air curtain performance in an operating mine. Mine results demonstrated the proof-of-concept and the potential for this control technology.

Potential Outcome

The leading roof bolter manufacturer in the United States has expressed an interest in furthering the development of this technology. After a joint meeting among NIOSH, MSHA, the mine operator, and the bolter manufacturer, it was agreed that NIOSH, the mine operator, and the bolter manufacturer would continue this research to refine and improve the air curtain with the goal of reaching commercialization. Successful implementation of this technology will result in a significant reduction in exposures to respirable dust and silica among roof bolter operators, particularly when they are forced to work downwind of continuous miners. Field tests of this system should be completed in early 2007, with a bolter manufacturer offering the technology on its equipment by 2008.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Effective Control of Respirable Dust in Underground Coal Mines in the United States Colinet-JF; Goodman-GVR; Listak-JM; Chekan-GJ; Rider-JP; Pollock-DE; Thimons-ED In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AuslMM, Victoria, Australia, 2005; :129-134	2005	Publication	Respiratory diseases
Evaluation of Methods for Controlling Silica Dust Exposures on Roof Bolters Goodman-GVR; Organiscak-JA 2002 Transactions, Society for Mining, Metallurgy, and Exploration, Vol. 312; :133-137	2002	Publication	Respiratory diseases
Laboratory Evaluation of a Canopy Air Curtain for Controlling Occupational Exposures of Roof Bolters Goodman-GVR; Organiscak-JA Proc Seventh International Mine Ventilation Congress, (Krakow, Poland) 2001 Jun; :299-305	2001	Publication	Respiratory diseases
Emerging Technologies Control Respirable Dust Exposures for Continuous Miner and Roof Bolter Personnel - Accepted for presentation and publication at 11th US/North American Mine Ventilation Symposium, Pennsylvania State University, State College, PA, June 5-7, 2006	2006	Publication	Respiratory diseases
Reducing Roof Bolter Operator Dust Exposures with a Canopy Air Curtain - Mining Engineering	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Methane Control Handbook

Background

The potential hazards associated with methane gas emissions in underground mines have been well researched and documented. Over the past 20+ years, researchers from the U.S. the Bureau of Mines and NIOSH have developed techniques to identify and control these gas emissions. The problem with all these results is that a single specific source of relevant information has never been compiled for individuals needing to understand how to identify the problem and implement a workable combination of controls. Researchers within NIOSH and the Mine Safety and Health Administration, working with others in the industry, have written various chapters in a handbook that will address methane problems in coal mining, metal and nonmetal mining, and tunneling. All aspects of methane control will be documented, so the reader will be provided with a comprehensive menu of approaches for controlling methane.



Methane gas and dust released at the working face

Potential Outcome

This work is scheduled to be published sometime late in calendar year 2005 or early in 2006. The potential impact of this publication is that it will provide the first comprehensive source of information that can specifically assist individuals who are tasked with predicting, identifying, and controlling underground methane emissions.

Outputs

1 Planned or completed output

Title	Year	Output Type	Strategic Goal
Handbook for Methane Control in Mining - NIOSH IC	2006	Publication	Mine disasters

Potential Intermediate Outcome for Respiratory Diseases

Control Technology for Coal Worker Pneumoconiosis (CWP) Hotspots

Background

Analyses of data obtained from the National Coal Workers' X-Ray Surveillance Program along with data obtained from the Miners Choice x-ray program have shown that mine workers from small mines in the southern Appalachian region are showing almost three times the national average of CWP and nearly five times the rate of pulmonary massive fibrosis (PMF). In response, NIOSH is initiating a program to implement improved dust control technologies into these mines to address this problem. NIOSH researchers will utilize MSHA compliance sampling results to identify mines of interest in the southern



Longwall shearer operating in lower seam

Appalachian region. Researchers will then visit MSHA offices in the region to gather and analyze data from dust control plans on file for each mine. Information from mine inspector reports on production rates, mine equipment types, mining practices, and other characteristics specific to the mines will also be noted. Dust surveys will be conducted at selected mines to determine problem areas, to assess the state of control technology being employed, and to determine where additional control technology is needed. The small mines involved may require individual dust control technologies because of their limited budgets and specific operating conditions. NIOSH will conduct laboratory and field research to optimize existing technologies and to develop new technologies that will have a higher probability of acceptance and success in these mines.

Potential Outcome

As NIOSH researchers learn what dust control technologies are the most practical for these small operations, regional workshops will be conducted to transfer findings to mine operators and miners to improve knowledge about successful dust controls. By 2007, NIOSH researchers should have an initial understanding of why these mining operations have such a high prevalence of CWP. By 2008, information on how to control the dust in these mines effectively and economically should be available for publication. The potential future impact is that cost-effective dust control technology specific to these small mines will be developed and implemented with a high likelihood of having a positive impact on reducing the rate of both CWP and PMF.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Characterizing Dust Exposures and Controls for Mines Operating in the Southern Appalachian Region - Coal Age	2008	Publication	Respiratory diseases
Dust Control for Mines Operating in the Southern Appalachian Region - workshops in KY, VA and WV	2009	Workshop, Seminar, or OIB	Respiratory diseases
Factors Impacting Successful Dust Control in Small Mines - SME Transactions	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Measuring Diesel Particulate Matter with Diesel Detective Monitoring Technology

Background

The efficacy of diesel particulate matter control depends on the ability to measure engine emissions quickly and effectively. A NIOSH-patented detector tube technology is being used to solve this problem. NIOSH work on this project has been conducted jointly through a Cooperative Research and Development Agreement with SKC, Inc., of Eighty-Four, PA. The device, known as the Diesel Detective, will enable front-line personnel to determine quickly the particulate emission levels of an engine and determine if control technology maintenance may be required. Because of this NIOSH research, the Department of Minerals Resources, New South Wales, Australia, has tested the prototype Diesel Detective in laboratory and field trials and has recommended use of the technology in Australian mines.



Triplicate Diesel Detectives in a diesel engine exhaust

Potential Outcome

In response to these U.S. and Australian research results, SKC, Inc., is funding the commercialization of the instrument. In 2005, BHP-Billiton (the largest mining company in the world) published an article entitled "Diesel Emissions Management." In this report, the authors recommend that the Diesel Detective be used by all diesel fleet managers to examine engines and isolate those in need of particulate emission control. SKC, Inc., now has orders in-hand for this device and is working on commercialization. This development has the potential to provide the entire mining industry with an inexpensive and reliable tool for evaluating the performance of diesel emission controls in a timely manner. In U.S. coal mines where no ambient air testing is done, this device will make it possible to evaluate the performance of DPM control filters to test for failures during routine maintenance quickly. In metal/nonmetal mines, it will provide a valuable tool to engineering and maintenance personnel to find out if a filter is performing as designed. The technology is now available and proven and should be commercially available in 2006.

Outputs

4 Planned or completed outputs

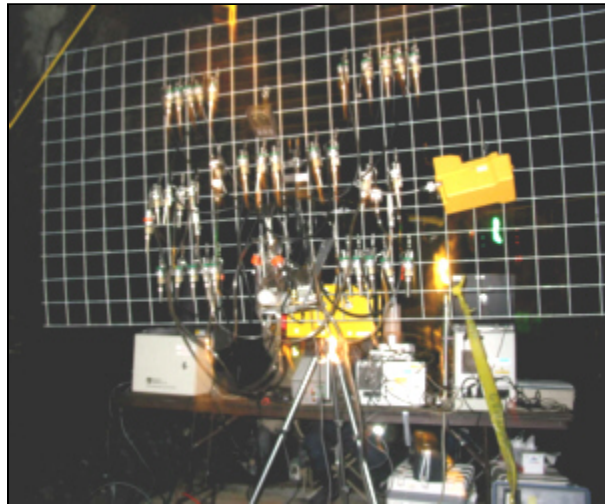
Title	Year	Output Type	Strategic Goal
A Continuous Personal Diesel Emission Exposure Monitor - Engineering & Mining Journal	2009	Publication	Respiratory diseases
A Differential Pressure Method used to Monitor Efficiencies of Diesel Emission Control Technologies - NIOSH RI	2007	Publication	Respiratory diseases
A Direct Method to Measure Relative Levels of Engine Tailpipe Diesel Particulate Matter - Journal of Aerosol Science	2006	Publication	Respiratory diseases
Differential Pressure Method to Measure Elemental Carbon in Undiluted Diesel Exhaust - Environmental Science & Technology	2006	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines

Background

Continual expansion of the use of diesel engines in the mining industry and the uncertainty associated with the long- and short-term effects of diesel exhaust emissions on miners' health have focused attention on the control of emissions from diesel engines. The potential exposure to diesel emissions has raised a host of health concerns and garnered interest from various regulatory agencies throughout the world. In 2001, the Mine Safety and Health Administration (MSHA) promulgated two rules, one (30 CFR 57.5060) limiting exposures of underground metal and nonmetal miners to total and elemental carbon and the other (30 CFR 72.500, 72.501, and 72.502) limiting diesel particulate matter (DPM) emissions from diesel-powered coal mining equipment.



Sampling grid at Stillwater Mine

To reduce miners' exposures to DPM and to abide by the measure of current U.S. regulations, NIOSH has formed partnerships with the U.S. underground mining community to work on identifying controls for the curtailment of DPM and gaseous emissions from both existing and new diesel-powered vehicles. To date, the replacement of older diesel engines with cleaner modern engines, improvements in diesel engine maintenance, and the implementation of various diesel emission control technologies, including diesel particulate filter systems and reformulated fuels, are all viewed as effective methods to reduce DPM concentrations in mine air. To assist mine operators with the potentially complicated process of choosing the proper DPM control strategy, NIOSH will develop guidelines to reduce diesel particulate matter in coal, metal, and nonmetal mines.

Potential Outcome

The long-term impact of these guidelines will be that mine operators will have correct guidance as they work to develop a successful DPM control strategy. These guidelines will lay out a multifaceted approach for DPM control, including the use of newer, cleaner engines; alternative fuels; exhaust after-treatment systems; and proper engine maintenance. NIOSH is currently working on several levels to gain the necessary knowledge to complete these guidelines. In the previous 3 years (2002 to 2004), NIOSH completed four field studies at the Deer Creek coal mine and at the Stillwater Mine to evaluate the effectiveness of various filters and alternative fuels as to their ability to reduce DPM concentrations in mine air.

NIOSH is also testing a continuously regenerating trap at the University of Minnesota. If successful, this system will give the mining industry a diesel particulate filter that can be installed and forgotten, at least for 250 hours, or the period between normal engine maintenance. A DPM tailpipe monitor that monitors in real time is also being developed to assist mine mechanics with proper maintenance of mine vehicles and ensure that control technologies are effective.

A filter selection guide that walks mine operators through each step in choosing a proper filter is being designed; currently NIOSH is working with the Queenstake Mining Co., of Elko, NV, to evaluate the effectiveness of the guide. Once these guidelines are finalized, NIOSH will sponsor a series of workshops to explain the guidelines in detail to operators. In addition, the guidelines will be available to all operators through the NIOSH Internet and in NIOSH publications.

Outputs

12 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Diesel Particulate Matter Control Technologies and Measurements in US Mines Mischler-SE; Bugarski-AD; Schnakenberg-GH In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; : 263-274	2005	Publication	Respiratory diseases
Differential Pressure as a Measure of Particulate Matter Emissions from Diesel Engines Mischler-SE; Volkwein-JC Environ Sci Technol 2005 Apr; 39(7):2255-2261	2005	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine Bugarski-AD; Schnakenberg-GH; Noll-JD; Mischler-SE; Patts-LD; Hummer-J; Vanderslice-SE; Crum-M; Anderson-R Proceedings of Diesel Particulate in Mining Conference, Sponsored by Australian Journal of Mining, Yeppoon, Queensland, Australia, June 8-9, 2004	2004	Publication	Respiratory diseases
Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines - NIOSH RI	2009	Publication	Respiratory diseases
Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines." - NIOSH internet	2009	Web document	Respiratory diseases
A series of workshops for coal mine operators explaining the "Guidelines to Reduce Diesel Particulate Matter in Coal Mines"	2009	Workshop, Seminar, or OIB	Respiratory diseases
A series of workshops for metal/nonmetal mine operators explaining the "Guidelines to Reduce Diesel Particulate Matter in Metal, and Nonmetal Mines"	2009	Workshop, Seminar, or OIB	Respiratory diseases
Reformulated Fuels and After Treatment Technology Effectiveness in Controlling Diesel Emissions. Stillwater Mining Co. Nye Mine Study - NIOSH RI	2006	Publication	Respiratory diseases
Report to the partnerships on the results from the Jerritt Canyon mine study - Partnership Report	2007	Publication	Respiratory diseases
Report to the partnerships on the results of the Johnson-Matthey CRT tests - Partnership Report	2006	Publication	Respiratory diseases
Report to the partnerships on the results of the Rohmac heat exchanger tests - Partnership Report	2006	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Diesel Particulate Filter Selection Guide

Background

Currently, a wide range of applications are available to control diesel particulate matter (DPM) emitted from engines in mine vehicles effectively. One effective control option is the use of a diesel particulate filter. Because of the wide variety of function and applicability of the filters, mine operators have found it difficult to select the proper one to use with specific pieces of underground equipment. Factors that include duty cycle, engine exhaust temperature, and limited available volume constraints must be considered when selecting the proper filter. To assist mine operators with this potentially complicated process, NIOSH researchers have developed a "Filter Selection Guide." This handbook is currently available through Internet links on both the NIOSH mining and Mine Safety and Health Administration Websites. The "Filter Selection Guide" walks operators through each step of the selection process and outlines the information necessary to complete each step. At the completion of the guide, operators are provided the best filter options to control DPM emissions.



Particulate filter designed to reduce diesel engine emissions

Potential Outcome

The long-term impact of the "Filter Selection Guide" is that it will provide mine operators with correct guidance for selecting filter-based diesel emission controls and will avoid the unnecessary and costly expense of installing inappropriate controls. Use of this guide will enhance the potential for miners to be better protected from diesel emissions. To obtain more practical knowledge that would be incorporated into the guide, NIOSH is currently working with the Queenstake Mining Co., of Elko, NV, to evaluate the guide's effectiveness in assisting mine personnel in choosing the appropriate diesel particulate filter for various diesel-powered vehicles used in their operation. This work will add significant real-world input to the guide. The research should be completed in early 2007, and the guide updated with new information by early 2008.

Outputs

7 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Metal and Nonmetal Diesel Particulate Filter Selection Guide Schnakenberg-GH; Bugarski-AD; Angel-J; Saseen-G Web document, http://www.msha.gov/nioshnmnfilterselectionguide/dpmfilterguide.htm	2005	Web document	Respiratory diseases
Long-Term Evaluation of Diesel Particulate Filter Systems at Inco's Stobie Mine Stachulak-JS; Conard-BR; Bugarski-AD; Schnakenberg-GH Proceeding of the Eighth International Mine Ventilation Congress, Brisbane, Queensland, Australia, July 6-8, 2005	2005	Publication	Respiratory diseases
Diesel Particulate Matter Control Technologies and Measurements in US Mines Mischler-SE; Bugarski-AD; Schnakenberg-GH In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; : 263-274	2005	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
Evaluation of Diesel Emission Control Technologies Used in U.S. Underground Coal and Non-Coal Mines Schnakenberg-GH; Bugarski-AD; Mischler-SE; Noll-JD Proceedings of the 31st Intl Conf of Safety in Mines Res Institutes, Brisbane, Australia, Oct 2-5, 2005; :277-280	2005	Publication	Respiratory diseases
An Update on the Metal and Nonmetal Diesel Particulate Filter Selection Guide - web based publication	2008	Web document	Respiratory diseases
From Theory to Practice: Examining Diesel Exhaust Filter Implementation and Performance in the Jerritt Canyon Mine - NIOSH RI	2007	Publication	Respiratory diseases

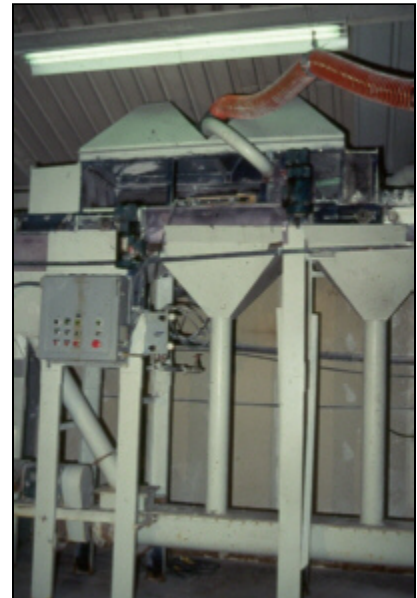
Potential Intermediate Outcome for Respiratory Diseases

Cooperative NIOSH/IMA-NA Dust Control Handbook for Mineral Processing Plants

Background

Workers performing a vast array of different job functions at mineral processing operations are often overexposed to silica and other respirable dusts. Health and safety specialists and engineers are constantly looking for new engineering control techniques to lower respirable dust exposures for workers at these facilities. NIOSH and the Industrial Minerals Association-North America (IMA-NA) recently formed a dust control task group in an effort to improve dust control at processing operations. This task group is mainly composed of health and safety specialists from a number of mineral processing corporations, as well as members from IMA-NA and NIOSH. The initial goal of this dust control task group is to pursue the development of a dust control handbook for mineral processing plants that would provide information on proven and effective control technology to lower workers' respirable dust exposures at mineral processing plants. This handbook is to be fashioned after the ACGIH's Industrial Ventilation Manual: A Manual of Recommended Practices. Chapters within the handbook

will be written to address the different dust exposure topics of concern and provide engineering control techniques to lower workers' exposures to respirable dust. It is anticipated that much of the information for this handbook will come from the current NIOSH mineral processing dust control handbook. However, new information will be added. This handbook also will address a wider array of workers with a significant emphasis on maintenance workers, who are often overlooked with respect to dust exposure, but who are often highly exposed.



Bag cleaning unit installed in plant

Potential Outcome

Once completed, this handbook will be an extremely valuable resource to the industry by providing information on proven and effective dust control technology to lower workers' respirable dust exposures throughout the minerals processing industry. It is anticipated that this joint effort will start in 2006 and continue through 2008, with the handbook coming out in 2009.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Control Technologies Being Used to Control Silica Exposures in Mineral Processing Plants - Aggregates Manager	2008	Publication	Respiratory diseases
Dust Control Handbook for Mineral Processing Operations - NIOSH IC	2009	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Inline Series Spray Scrubber

Background

Mining machine operators have some of the highest frequencies of overexposure to both respirable coal and silica dust. From 2000 through 2004, over 8,500 samples collected from operators of continuous miners by MSHA inspectors and mine operators exceeded the 2 mg/m³ respirable dust standard. Although water spray dust suppression systems continue to make significant contributions toward reducing dust exposure among miners, NIOSH has identified diminishing returns, and simple increases in pressure and/or quantity have not adequately provided the dust control needed to reach permissible exposure levels, particularly when dust standards are lowered due to excessive silica in the samples. To improve dust capture by water sprays operated at the pressures typically found in underground mines, NIOSH has developed a portable inline series spray scrubber to improve removal of localized airborne dust emitted at the source. Laboratory results show that the inline spray scrubber can move between 484 to 679 ft³/min of air and achieve 69% to 81% respirable dust capture efficiencies when operated at 250 psi. NIOSH laboratory and field research studies are continuing in order to optimize this dust scrubber technology.



Adjusting airflow through water-powered scrubber

Potential Outcome

Use of these portable scrubbers close to the source of dust generation on a mining machine is expected to reduce the amount of airborne dust resulting in reduced exposures for mining machine operators. This technology will also likely have applications outside of mining. For example, inline spray scrubbers could be used for a number of applications in mineral processing facilities. Laboratory tests of this concept should be completed in 2007, and information published in late 2007 or early 2008.

Outputs

3 Planned or completed outputs

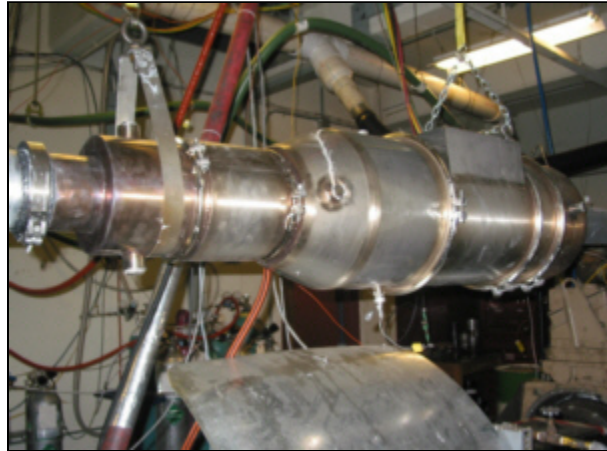
Title	Year	Output Type	Strategic Goal
Development of a Lower Pressure, Water-Powered Spot Scrubber for Mining Applications <small>Organiscak-JA; Pollock-DE SME preprint 05-103. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 2005; :1-9</small>	2005	Publication	Respiratory diseases
Controlling Dust Generation in a Dimension Stone Shop with a Low-Pressure Scrubber - Rock Products Magazine	2006	Publication	Respiratory diseases
Utilizing Spot Scrubbers to Reduce Dust Levels on Continuous Mining Machines - SME transactions	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Evaluation of a Continuously Regenerating Diesel Exhaust Trap with Nitrogen Dioxide Control

Background

The diesel particulate filter has been shown to reduce the amount of diesel particulate matter (DPM) emitted from diesel-powered vehicles effectively. However, the mining industry has voiced concern regarding the amount of maintenance required to institute a diesel particulate filter program. A major issue is the necessity to clean accumulated DPM from the filter. At high exhaust temperatures, DPM can be removed through combustion often initiated by a catalyst, a process known as regeneration. However, using a catalyst for regeneration often leads to the release of excessive quantities of nitrogen dioxide (NO₂). This is a concern because NO₂ is a very toxic gas that affects the throat and lungs. It is a fast-acting substance having a ceiling value of only five parts per million parts of air. To supply the mining industry with a diesel particulate filter that both effectively reduces DPM emissions and allows for low-temperature natural regeneration, NIOSH is working with Johnson Matthey, Inc., of Taylor, MI, to develop and test a continuously regenerating trap with NO₂ control. This device continuously regenerates the filter medium with NO₂, which is produced by a catalyst positioned directly upstream of the filter. NO₂ is effective in catalyzing low-temperature DPM combustion soot that has accumulated on the DPF. The continuously regenerating trap system is currently used in road vehicles. A problem with NO₂ slip, the process whereby NO₂ is emitted from an exhaust pipe, has prevented this technology from being used in underground mines. To solve NO₂ slip, Johnson-Matthey has developed a NO₂ control that is currently being tested under a NIOSH contract at the University of Minnesota's Center for Diesel Research in Minneapolis, MN.



Johnson Matthey continuously regenerating trap being evaluated at the University of Minnesota

Potential Outcome

If successful, this system will give the mining industry a diesel particulate filter that will be simple to install and use for at least 250 hours, or the period between normal engine maintenance. This should solve one of industry's major problems relative to instituting a filter program. Successful development of this continuously regenerating trap will directly relate to lower DPM exposures for miners. Research at the University of Minnesota should be completed by late 2006, and if successful, followed by in-mine tests of the system in a U.S. metal/nonmetal mine (under the Metal/Nonmetal Diesel Partnership) in 2007. Results should be published and available to the industry in late 2007.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Evaluation of a Continuously Regenerating Diesel Emission Trap for use Underground - proceedings of the Mining Diesel Emission Conference	2007	Publication	Respiratory diseases
Bugarski, A.D. and Schnakenberg, G.H. Effects of Control Technologies on Diesel Emissions in Underground Mines. NIOSH Report of Investigation. 2008	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Longwall Dust Surveys

Background

Historically, mine workers on longwall faces have had the highest degree of exposure to underground dust relative to the 2 mg/m³ dust standard. As longwall production increases, mine operators struggle with maintaining consistent compliance with the mandated dust standard. In compliance samples collected from 2000 through 2004, 19% of the return side face workers, 11% of the tailgate-side shearer operators, and 10% of the jacksetters exceeded the 2 mg/m³ dust standard. Production levels are projected to increase further, heightening the need for improved longwall control technologies. NIOSH researchers are conducting benchmark surveys in approximately 20% of the U.S. longwalls in an effort to identify the major sources of dust generation, the state of the art of longwall dust control technology, successful control technologies, and issues of additional need. To date, longwall surveys have been completed in six longwalls.



Evaluating directional water sprays on a longwall shearer

Potential Outcome

At the completion of these surveys, information on successful controls will be summarized in a handbook. The surveys will be completed by late 2006, and the information will be summarized and ready for publication by late 2007. This information will be disseminated throughout the longwall mining industry to provide guidance for reducing dust levels on longwalls. Gaps or needs for additional control technologies will also be identified and addressed through future research. The potential impact of this work lies in the fact that all longwall mining operations will have access to the latest proven longwall dust control technologies with guidance for implementing these controls.

Outputs

4 Planned or completed outputs

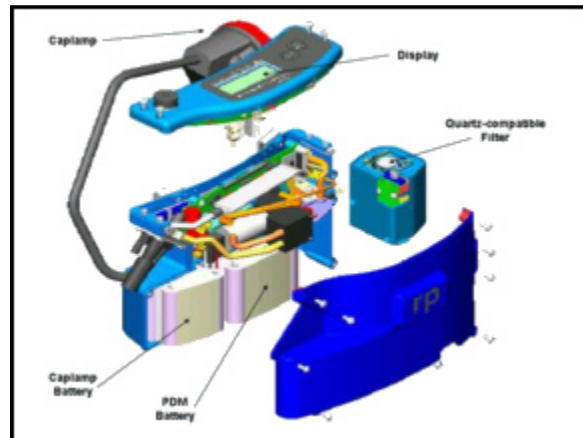
Title	Year	Output Type	Strategic Goal
Benchmarking Effective Longwall Dust Controls - proceedings of Longwall USA	2007	Publication	Respiratory diseases
Dust Controls on Longwalls - Assessment of the State-of-the-Art - proceedings 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
Factors Impacting Shield Dust Entrainment in High Velocity Airstreams - SME transactions	2008	Publication	Respiratory diseases
Longwall Dust Control Handbook - NIOSH IC	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Filter Materials for Silica Analysis When Using the Personal Dust Monitor

Background

The development and evaluation (both laboratory and field) of the personal dust monitor have been successful. However, the filter material currently being used in the monitor is not effective in analyzing silica, an airborne respirable dust commonly found in underground mines. NIOSH researchers have recently identified a filter material that is both compatible with the analytical method used to quantify airborne silica and stable when measuring total respirable dust mass.



Potential Outcome

NIOSH has applied for a patent for this development. Successful implementation of this research will increase the utility of the personal dust monitor for routine monitoring of coal miners' exposure to not only coal mine dust, but also to the fraction of silica in that dust. Laboratory tests of this filter material are near completion. Thermo Electron Co., the producer of the personal dust monitor technology, is interested in licensing the technology for the monitor. In 2006, the information on this technology will be shared with Thermo-Electron, which will provide it to industry.

An expanded view of the personal dust monitor showing the location of the quartz-compatible filter

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Implementing Infrared Determination of Quartz Particulates on Novel Filters for a Prototype Dust Monitor - Journal of Occupational and Environmental Hygiene	2007	Publication	Respiratory diseases
Locating a Filter Medium Suitable for Quartz Analysis with the Personal Dust Monitor - proceedings SME Annual Meeting	2007	Publication	Respiratory diseases
Patent on filter medium suitable for quartz analysis with PDM	2007	Patent	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases Facilitating the Use of Personal Dust Monitors as a Means of preventing Coal Workers' Pneumoconiosis

Background

An important potential impact of PRL training research during the next few years will be the development of effective training materials and health communications for coal miners and mine managers on how the personal dust monitor can be used to reduce workers' exposure to respirable dust. In recent years, coal workers' pneumoconiosis (CWP) has contributed to the deaths of approximately 1,000 people in the United States each year. Federal black lung program payments totaled more than \$1.5 billion distributed to nearly 190,000 beneficiaries in 1999.

NIOSH, in collaboration with Rupprecht & Patashnik Co., Inc., of Albany, NY, recently developed a personal dust monitor. This new device represents a major advance in the tools available for assessing coal miners' exposures to respirable dust levels. Over the next 2 years, NIOSH human factors researchers will collect data to identify how personal dust monitor use affects miners' exposures to respirable dust. First, researchers will identify several specific examples of how miners use information about the monitors to discover which parts of their jobs and/or which aspects of their work environment may cause them to be overexposed to respirable dust. Second, they will identify the types of changes that miners and mine managers could implement to reduce their exposure. Researchers will develop material for communicating this important information to miners and mine managers. They will also develop training modules to (1) explain the capabilities and use of personal dust monitors to coal miners and (2) explain how to download data, clean the monitor unit, and program it for the next shift of dust sampling to mine health and safety technicians.



Miner wearing PDM

Potential Outcome

Once miners know how to use properly the information that a personal dust monitor is capable of providing, they should start adjusting their workplace and work procedures in ways that should reduce their exposure to respirable coal dust. As miners' exposure to respirable dust is reduced, the incidence of CWP should significantly decline, and miners' longevity and quality of life should significantly improve. This work will be completed by the end of 2007.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Examples and Strategies for using the PDM to Reduce Miners' Exposures to Respirable Dust - Coal Age	2007	Publication	Respiratory diseases
Miners' opinions about the PDM and how they can be used to reduce respirable dust exposure - Journal of Intl Society for Respiratory Protection	2007	Publication	Respiratory diseases
New Training on the Use and Maintenance of the PDM - proceedings SME conference	2007	Publication	Respiratory diseases
Training Module for Coal Mine Health and Safety Technicians on how to Maintain the PDM - NIOSH IC	2006	Publication	Respiratory diseases
Training Module for Coal Miners on the Purpose and Operation of the PDM - NIOSH IC	2006	Publication	Respiratory diseases
Miners' Opinions about the PDM and how they can be used to Reduce Respirable Dust Exposure - proceedings SME conference	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Assessing the Performance of a Heat Exchanger to Reduce Outby Diesel Exhaust Temperatures

Background

Presently, MSHA requires heavy-duty, diesel-powered outby vehicles used in coal mines to be equipped with a diesel particulate filter. For inby diesel-powered equipment, the exhaust temperature is regulated, and thus disposable paper filters can be used in conjunction with either water scrubbers or aqueous heat exchangers. Both of these systems cool the exhaust and reduce the potential for the paper filter to ignite. However, because of the high expense and maintenance problems associated with water scrubbers or heat exchangers, coal mine operators are reluctant to apply these systems to outby engines where exhaust temperatures are not regulated. Options

are limited. One is to use high-temperature disposable filters on outby equipment. However, heavy-duty outby vehicles can have exhaust temperatures as high as 1300°F. Due to these high exhaust temperatures, some coal mines have experienced filter fires. The filter itself does not burn, but the solid emissions trapped by the exhaust and other engine hydrocarbons that build up on the filter can ignite. To find practical alternatives to this problem, NIOSH has collaborated with Rohmac, Inc., of Mount Storm, WV, on a project to design, fabricate, and evaluate an exhaust gas cooling device for diesel engines in conjunction with a high-temperature disposable diesel particulate filter for outby use. This device will reduce the exhaust temperature to less than the 650°F maximum temperature recommended by manufacturers, thereby reducing the possibility of fire and providing a necessary emission control option for coal mine operators. NIOSH researchers are currently evaluating this heat exchanger on a diesel-powered locomotive in an underground coal mine to determine its effectiveness in reducing exhaust temperatures.



Rohmac system installed on a diesel-powered locomotive

Potential Outcome

If this research is successful, it will provide the coal industry with a practical alternative to using paper filters on outby diesel equipment and reduce miners' exposures to diesel particulate matter. In-mine tests of this system should be completed in early 2006, and the results made available to the industry by late summer 2006.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Effects of Coal Mine Diesel Emission Control Technologies - NIOSH RI	2007	Publication	Respiratory diseases
Performance Evaluation of an Exhaust-gas Cooling Device in an Underground Coal Mine - proceedings SME Annual Meeting	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Dust Capture and Induced Airflow of Various Spray Nozzle Designs

Background

Water sprays have been used throughout the mining industry as a primary means of controlling respirable dust. In addition to wetting, the spray pattern of water sprays can be used to induce air movement. NIOSH researchers have shown that air movement induced by unenclosed water sprays mounted on coal-mining machines can be beneficial (longwall shearer-clearer) or detrimental (dust rollback on continuous miners) to controlling machine operators' exposures to respirable dust. While higher water spray pressures increase dust capture in enclosed spaces, they can also increase spray-induced airflow and, as a result, reduce dust capture in unenclosed spaces. NIOSH has characterized water spray droplet formation, air inducement, and dust capture efficiency for various spray nozzle types. Results indicate that hollow cone and wider spray-cone-angle nozzles generally generate smaller and slower water droplets, which induce more airflow and have lower dust capture efficiencies. A flat spray pattern and sprays with narrower discharge angles tend to generate larger and faster water droplets, which induce less airflow and have higher dust capture efficiencies. This fundamental information about sprays will be verified in the laboratory and the field and applied to improvements in current spray system designs by reducing the detrimental effects of spray nozzles that push dust over machine operators.



Unconfined spray on longwall shearer

Potential Outcome

Completion of these studies can demonstrate the pros and cons of spray nozzle types and their operating parameters to optimize respirable dust controls. This information, when fully understood and verified, will be used to educate the mining industry about optimizing the design of machine-mounted water spray systems to improve dust capture and reduce operators' exposures to dust. This research should be completed by late 2008, and the findings made available to the industry in early 2009.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Spray Characterization for Coal Mine Dust Removal Gemci-T; Chigier-N; Organiscak-JA In: Proceedings of the Ninth International Conference on Liquid Atomization and Spray Systems (Sorrento, Italy, July 13-18, 2003), 2003	2003	Publication	Respiratory diseases
Airborne Dust Capture and Induced Airflow of Various Spray Nozzle Designs - Journal of Occup & Environmental Hygiene	2007	Publication	Respiratory diseases
Improved Utilization of Water Sprays for Reducing Worker Dust Exposure in Mining - Mining Engineering	2009	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Open Structure Design

Background

Workers at mineral processing facilities are often exposed to high levels of hazardous respirable dust, generally in the form of silica dust. Federal compliance records have shown that workers at these facilities have some of the higher silica exposure rates in the entire metal/nonmetal mining industry, especially in those operations processing silica sand. Many different types of structures and materials have been used to build mineral processing facilities over the past few decades. Although the structure type and building material have not historically been considered factors with respect to silica exposure, recent NIOSH studies have addressed this issue. NIOSH researchers conducted field surveys to evaluate respirable dust levels associated with three different types of processing plants: closed metal structure, closed block structure, and an open structure design. This research determined that an open structure design for mineral processing operations was superior to walled structures in terms of reducing silica exposures. Preliminary findings show that for similar production rates, the open structure is far superior because it eliminates the dust gradients that form throughout a closed structure during the course of a shift. In the open structure design, the natural environment acts as an effective method of diluting and carrying away dust generated and liberated during product processing.



Open structure plant sampled for project

Potential Outcome

It appears that the use of open structure designs shows great promise in reducing silica exposure of workers in mineral processing operations. NIOSH is discussing work with the Industrial Minerals Association-North America to further evaluate the impact of structural design on dust exposures in mineral processing operations. While the preliminary work is completed, future work would likely run through 2007, with final results available in 2008.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Impact of Structural Design on Dust Levels in Mineral Processing Plants - NIOSH RI	2006	Publication	Respiratory diseases
Modifying the Structure of Processing Plants to Reduce Dust Levels - Aggregates Manager	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Hydrogen-Powered Mine Vehicle Reduces Miner Exposure to Diesel Emissions

Background

The use of hydrogen as a fuel to power underground mine vehicles has the potential to reduce significantly worker exposures to the particulates and toxic gasses generated by diesel-powered vehicles. The first step to implementation of new hydrogen technologies is to establish safe practices for handling and use of the hydrogen fuel. A prototype hydrogen-fueled mining vehicle, dubbed the Zero Emission Utility Solution (ZEUS), was outfitted with the safety systems necessary for MSHA-compliant underground deployment. ZEUS is a modified EIMCO 975 articulated utility



Zero Emissions Utility Solution at the Stillwater mine

vehicle designed for underground use. A naturally aspirated water-cooled Caterpillar 3304 diesel engine was re-engineered to burn hydrogen. Fuel storage consisted of a modular metal hydride system mounted within the trailer flatbed. Metal hydride storage of hydrogen is the same technology under widespread development for fuel-cell technology. In addition to common safety features (e.g., ROPS and FOPS protection, back-up alarm, lamps, and seat belts), the vehicle was equipped with five sensors to detect gaseous hydrogen at low levels, yet minimize false readings from other gases and compounds. The hydrogen sensors also address the possibility for failures of the fuel storage and distribution systems. Refueling presents a hazard different than that posed by the liquid fuels miners are traditionally trained to use; therefore, a protocol for safe refueling was developed for the demonstration.

ZEUS, with its unique safety systems, was successfully demonstrated at the Stillwater Mine in Nye, MT, in 2004. This was the first time a hydrogen-fueled vehicle was operated in an underground mine in the United States. The demonstration of this vehicle in a mine provided regulators and industry with the opportunity to evaluate the safety systems and controls necessary for advancing the use of hydrogen as an industrial fuel.

In addition to being highlighted in the Engineering & Mining Journal (September 2004), the demonstration was well publicized in the Montana press by the Billings Gazette (<http://www.billingsgazette.com>) and Stillwater County News (<http://www.stillwatercountynews.com>). ZEUS was also driven in three community parades in Montana towns near the mine - Fishtail, Red Lodge, and Columbus.

Potential Outcome

The introduction of hydrogen as an alternative fuel for underground mine vehicles opens new avenues for reducing miner exposure to diesel particulate matter (DPM), an identified health hazard. This research demonstrated that some vehicles in the mining fleet can be retrofitted to burn hydrogen safely. The application of hydrogen technology will likely be a last resort because it is still expensive; however, the cost of modular metal hydride storage for hydrogen will be reduced within the next 10 to 15 years. Where DPM controls are not feasible, hydrogen can be considered an alternative to diesel fuel for mine vehicles.

Potential Intermediate Outcome for Hearing Loss

Underground Metal Noise Control Guide

Background

An important enabling step for the application of existing noise control technology or the development of new technology is the identification of what controls currently exist and their effectiveness. Therefore, engineering noise control technologies used in or applicable to the mining industry are being documented and evaluated by NIOSH. Researchers visited a number of underground metal mines to study the effectiveness of the controls in terms of reducing worker exposure to noise. Another goal is to understand noise-generating mechanisms so new technology can be developed to reduce the sound levels to which workers are currently being exposed.



Measuring sound intensity on a LHD

Potential Outcome

Based on the finding of this study, a Noise Control Guidebook for Underground Metal Mines is being developed and will be completed in 2006. The guidebook will provide information on the basic noise controls currently in use in the industry and emphasize lessons learned over the course of the research. Such lessons include:

1. What controls work and what controls don't work.
2. Engineering noise controls that work on the surface may not work as well as expected underground.
3. Properly installed barriers are effective in providing noise reduction; improperly placed absorptive material has little to no effect on sound levels.
4. A noise problem should be verified before a solution is attempted.

An important benefit of the guidebook will be that the noise control information obtained from throughout the underground metal-mining industry will be distributed to other sectors of the industry. Use of the guidebook should lead to the use of more robust noise controls, which in turn, will reduce worker noise exposure and the risk of noise-induced hearing loss. The guidebook will be initially published as a NIOSH publication, and then the information will be disseminated to industry through partnership efforts, conferences, and workshops. The impacts of this guidebook on the mining industry are expected to begin in 2006 after the research findings are published.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Noise Exposure in Longwall Mining and Engineering Controls Research Bauer-ER; Podobinsk-DJ; Reeve- ER In: Proceedings of Longwall USA International Exhibition and Conference, June 13-15, Pittsburgh, PA, Intertec Publishing Corp.; :51-69	2001	Publication	Hearing loss
Assessment of Noise Controls Commonly Used on Jumbo Drills and Bolters in Western Underground Metal Mines Reeves-ER SME preprint 04-112. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :7 pp	2004	Publication	Hearing loss
Assessment of Noise Controls Commonly Used on Jumbo Drills and Bolters in Western United States Underground Metal Mines Reeves-ER Min Eng 57(1), 2005; :41-47	2005	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Testing and Evaluation of an Engineering Noise Control on a Longwall Stageloader Bauer-ER; Reeves-ER; Durr-TM; Zuchelli-DR; Armour-D SME preprint 05-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; :1-12	2005	Publication	Hearing loss
Reeves ER [2006]. Noise control in underground metal mining. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH IC) Publication No. In review, Dec.	2006	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Improved Hearing Protection

Background

Earmuffs, earplugs, and other hearing protectors can be effective adjuncts to noise controls in preventing noise-induced hearing loss, but they have some significant drawbacks. Reported usage rates are below 50%, and those workers who do wear hearing protection typically receive far less noise protection than they might expect. Because of poor fit, real-world protection levels are reported well below 50% of the rated protection determined in the optimal setting of a laboratory. Hearing protectors can also interfere with communication and localization of alarms and important ambient sounds.



Laboratory evaluation of hearing protection

To overcome these shortcomings, NIOSH is addressing both hearing protector technology and worker behavior. New research-based guidelines are being developed to match hearing protectors to the noise and task environments without impeding communication. A simplified "roll-pull-hold" technique was developed to make the critical earplug-donning steps easier to remember and perform correctly. An interactive training package for surface drill operators was developed using three-dimensional slides and extensively field tested with workers.

The researchers also investigated improvements to hearing protectors that would make them function better. A special lubricant currently marketed for easing the fitting of hearing aids was evaluated for use with earplugs. Subjects who used the lubricant were significantly more likely to obtain a good protective seal with their earplugs. Also, a new hearing protector technology with a built-in electronic dose and exposure feedback system was subjected to laboratory trials. The system uses inexpensive microphones built into the hearing protectors, and these were found to provide a useful approximation of the amount of hazardous noise reaching the user.

Potential Outcome

Research on improved training and hearing protector technologies was completed in 2005, and follow-on studies to evaluate peer feedback training will be complete in 2007. Beginning in 2003 and continuing through 2008, the results of these studies are being disseminated in a series of practical training products in print, video, and Web format. Hearing protector communication guidelines will be distributed as a Web-based decision tool that will help optimize the match between protectors and different work settings. These products will have an impact on the estimated 90% of miners and drill workers who need to wear hearing protection during at least part of their working shifts. By implementing the training and protector modifications and

improving protector usage rates and effectiveness, workers will significantly reduce their exposure to noise. For instance, the roll-pull-hold technique alone achieves 9 dB of improved protection that, if adopted industry-wide, would substantially reduce the incidence of noise-induced hearing loss.

Outputs

16 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
How to Wear Soft Foam Earplugs (Roll-Pull-Hold) Randolph-RF NIOSH 2003 Mar; :Video (RealMedia format, 30 seconds)	2003	Video	Hearing loss; Surveillance and training
How To Wear Soft Foam Earplugs Randolph-RF Web document, http://www.cdc.gov/niosh/mining/topics/hearingloss/earplug.htm	2003	Web document	Hearing loss
Wearing Hearing Protection Properly: A 3-D Training Aid for Drillers Barrett-EA; Calhoun-RA US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-107, Information Circular 9472, 2004 Nov :1-15	2004	Publication	Hearing loss; Surveillance and training
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Coal Noise Partnership Meeting/Workshop NIOSH Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Hearing Protection Training for Drillers Barrett-EA; Calhoun-RA National Ground Water Association, Water Well Journal, Volume 59, Number 12, Dec., 2005	2005	Publication	Hearing loss
Reeves ER [2008]. Guidelines for matching hearing protectors to workers and settings - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Barrett EA, Calhoun RA. Noise and hearing protection training for drillers. Professional Safety, In review, Dec, 2005: 18 pages. (refereed)	2006	Publication	Hearing loss
Randolph RF, Byrne DC, Hudak RL [2006]. Effectiveness of a simplified earplug insertion technique on attenuation performance. Journal of the Acoustical Society of America (refereed)	2006	Publication	Hearing loss
Byrne DC, Reeves ER [2006]. Analysis of non-standard noise dosimeter microphone positions. Journal of the Acoustical Society of America. (refereed)	2006	Publication	Hearing loss
Randolph RF, Kissell FN [2006]. The effect of an insertion lubricant on the noise attenuation of foam earplugs. Journal of Occupational and Environmental Hygiene. (refereed)	2006	Publication	Hearing loss
Byrne DC [2006]. Effectiveness of electronic earmuffs for underground miners. Mining Engineering Magazine (refereed).	2006	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

A Health Hazard Study of Surface Drilling Operations

Background

NIOSH researchers are developing engineering noise controls for air rotary surface drill rigs used in the mining and construction industries. Air rotary drills are used to drill vertical holes for such purposes as driving water and environmental monitoring wells, gathering geological information, and drilling blast holes during mining and construction projects. Field investigations of drill rigs and audiogram tests of operators have shown that operators of air rotary drill rigs are overexposed to noise. This research has developed two practical engineering controls and several training tools to help reduce hearing loss among operators of air rotary drills. A secondary aspect of the project is to develop materials to assist the industry with educating and training workers how to prevent hearing loss.



Partial cab protection for drill operator

Potential Outcome

The engineering controls developed as a result of this research will help prevent overexposure to noise among drill rig operators operating cab and noncab air rotary drilling equipment. One of the engineering controls, which will reduce sound levels in the operator's cab, can be easily retrofitted onto drill rigs already in production. The other control, which is referred to as "partial-cab," will protect operators on drill rigs having no operator's cab from sound levels over 90 dB(A). It is anticipated that the impact of these engineering controls could reduce an operator's daily noise dosage (time-weighted average for 8 hours) by 112% to 570%.

Six publications are currently being written to target the drilling industry's safety, educational, and training programs. These publications include formal classroom training materials, informal "tailgate" or "on-the-worksites" noise health and safety information pamphlets, and industry trade journals directed to awareness and prevention of hearing loss. The National Ground Water Association has shown an interest in promoting and distributing research results to its 60,000-person membership. All the knowledge gained from this project will be communicated to the construction and mining industries and research institutions via partnership councils, research journals, industry-centered publications, seminars, and conferences. The affects of this research on the drilling industry began in 2005 with many requests for the published training materials. The effects of the engineering controls are expected to begin in 2006, when test results are finalized and published.

Outputs

22 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Recognizing Noise and Dust Health Hazards for the Water Well Drilling Industry Ingram-DK; Matetic-RJ Workshop presented at request of the National Ground Water Association, National Convention and Exposition (Las Vegas, NV; December 13-15, 2000)	2000	Workshop, Seminar, or OIB	Hearing loss
Preventing High Insurance Premiums and On-the-Job Injuries: What are Poor Health and Safety Habits Costing You? Matetic-RJ; Ingram-DK Water Well Journal, 2001 Aug; :10-13	2001	Publication	Surveillance and training
Noise Health Hazards and How to Avoid Them Ingram-DK; Matetic-RJ Workshop presented at request of the Minnesota Water Well Association, Minnesota Water Well Association's 79th Annual Convention (St. Cloud, MN; January 29, 2001)	2001	Workshop, Seminar, or OIB	Hearing loss
Recognizing Noise and Dust Health Hazards for the Water Well Driller Ingram-DK; Matetic-RJ Workshop at the 46th Annual South Atlantic Well Drillers Jubilee (Myrtle Beach, SC; July 28-31, 2001)	2001	Workshop, Seminar, or OIB	Hearing loss
Summary of Noise Hazards and Engineering Applications to Reduce Noise Hazards Ingram-DK; Yantek-DS Workshop presented at request of the National Ground Water Association, National Ground Water Expo (Las Vegas, NV; December 8-12, 2002)	2002	Workshop, Seminar, or OIB	Hearing loss
Noise and Dust Hazards Associated with Water Well Drilling Ingram-DK; Matetic-RJ Workshop presented at request of New York's State Water Well Association, New York Water Well 2002 Annual Conference (Albany, NY; April 18-21, 2002)	2002	Workshop, Seminar, or OIB	Hearing loss
Are You Operating an Air Rotary Drilling Rig? Is It Loud? Ingram-DK; Matetic-RJ Water Well Journal, 57(7), 2003; :18-22	2003	Publication	Hearing loss
Hearing Safety: Water Well Drilling Industry Ingram-DK Workshop requested by the State of Ohio Environmental Protection Agency, Ohio's Annual Refresher Safety Training for the Ohio EPA Inspectors (Columbus, OH; October 22, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Hearing Conservation: the Ears Have It Ingram-DK; Matetic-RJ Workshop presented at request of the National Ground Water Association, National Ground Water Expo (Orlando, FL; December 9-12, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Hearing Safety and Machine Operation Ingram-DK; Moisan-P; Hudak-R Workshop presented at request of the New England Water Well Association, 2003 Annual Meeting (Marlborough, MA; March 21-22, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Wearing Hearing Protection Properly: A 3-D Training Aid for Drillers Barrett-EA; Calhoun-RA US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-107, Information Circular 9472, 2004 Nov :1-15	2004	Publication	Hearing loss; Surveillance and training
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Drill Rig Incident Barrett-EA; Calhoun-RA DHHS (NIOSH) Publication No. 2005-108, IC 9473, 2005 Feb; :1-51	2005	Publication	Hearing loss; Surveillance and training

Title	Year	Output Type	Strategic Goal
Coal Noise Partnership Meeting/Workshop NIOSH Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Water Well Safety Bits: Health And Safety Information For The Water Well Industry Reinke-DC Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-160, Information Circular 9483	2005	Publication	Hearing loss
Hearing Protection Training for Drillers Barrett-EA; Calhoun-RA National Ground Water Association, Water Well Journal, Volume 59, Number 12, Dec., 2005	2005	Publication	Hearing loss
Hearing Protection and Air Rotary Drilling - Part 1 Ingram-DK; Jurovcik-P National Driller. Vol. 26, No. 11, 2005; :10-15	2005	Publication	Hearing loss
Noise Exposure and Overhead Power Line (OPL) Safety Hazards at Surface Drilling Sites Reinke-DC; Homce-GT; Cawley-JC; Barrett-EA Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, December, 2005	2005	Publication	Hearing loss
Hearing Protection and Air-Rotary Drilling - Part 2 Ingram-DK; Jurovcik-P National Driller. Vol. 26, No. 12, Dec. 2005	2005	Publication	Hearing loss
Barrett EA, Calhoun RA. Noise and hearing protection training for drillers. Professional Safety, In review, Dec, 2005: 18 pages. (refereed)	2006	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Model Hearing Loss Prevention Program

Background

Hearing conservation programs are mandated for most U.S. mining operations. The conventional program, as codified in OSHA and MSHA regulations and widely taught to hearing conservationists, consists of noise exposure monitoring, hearing tests, promotion of hearing protection, education, and record-keeping. NIOSH best-practices guidelines recommend that the programs will be enhanced by including procedural audits, support of noise controls, program evaluation, and worker motivation (as an adjunct to education). With these enhancements, NIOSH refers to the ideal approach as a hearing loss prevention program.



Education and motivation are essential for an effective hearing loss prevention program

To provide information about the best way to implement a hearing loss prevention program, NIOSH needed to collect and evaluate best practices in a field setting. A cooperative agreement with the Pennsylvania State University resulted in a study that implemented many of the principles NIOSH put forth in its 1996 publication, "Preventing Occupational Hearing Loss: A Practical Guide."

Potential Outcome

The cooperative project was completed in 2004, and the results began to be disseminated through a series of workshops in 2005. The model hearing loss prevention program forms the basis for a new research study that incorporates worker participation in problem-solving. The new study, to be conducted during 2005-2008, will yield a series of intervention products, culminating in guidelines for implementing "best practices" through worker participation. These impacts will affect the majority of the workforce enrolled in hearing conservation programs. For instance, program enrollment rose from 7% to 82% of all coal miners from 2000 to 2003. If adopted, an effective hearing loss prevention program could substantially reduce the incidence of noise-induced hearing loss to an annual rate of less than 1% standard threshold shifts.

Outputs

14 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Model Hearing Conservation Program for Coal Miners Bise-CJ; Frank-T Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Final Report.- Cooperative Agreement U60/CCU315855	2004	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Coal Noise Partnership Meeting/Workshop NIOSH Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Reinke DC, Randolph RF [2008]. Guidelines on reducing barriers to adoption of noise control technologies - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Guidelines for worker empowerment for "best practices" hearing loss prevention program - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Team-based hearing loss communication interventions. Journal of Health Communication. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Evaluation of hearing loss prevention program. Ear and Hearing. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Effectiveness of participative teams for hearing loss prevention. Journal of Occupational Environmental Hygiene. (refereed)	2008	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss
Reinke DC, Randolph RF [2008]. Guidelines on reducing barriers to adoption of noise control technologies - Web content	2008	Web document	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Guidelines for worker empowerment for "best practices" hearing loss prevention program - Web content	2008	Web document	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Roof Bolting Machines

Background

NIOSH is working with the Noise Partnership Committee to evaluate and develop various controls for reducing noise related to roof bolting machines. MSHA data indicate that this machine is third among equipment that exceeds 100% operator dosage in coal mining and second in underground coal mining. The goal of this research is to determine the major contributors to an operator's noise exposure during the drilling and bolting cycle and then reduce the noise generated during these cycles by 10 dB(A). The investigation will provide methods and solutions for minimizing overexposure to noise among operators of roof bolting machines.



Sound power testing of a HDDR roof bolter

Potential Outcome

Research on engineering noise controls for roof bolting machines will be completed in 2007. To raise industry awareness of these controls, results will be disseminated through publications in journals and trade magazines and presentations at industry briefings related to noise exposure in the mining industry. By reducing roof bolting machine noise by 10 dB(A), it is anticipated that 90% of roof bolting machine operators' exposure to noise will fall below MSHA's permissible exposure limit.

Outputs

17 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Sound Power Level Study of a Roof Bolter Peterson-JS; Kovalchik-PG; Matetic-RJ SME Preprint No. 05-72, 2005 SME Conference, Salt Lake City, Utah, 2005; :8 pp	2005	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complan/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complan/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Coal Noise Partnership Meeting/Workshop NIOSH Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Guidelines on effective engineering noise controls for roof bolting machines - NIOSH numbered publication	2006	Publication (guidelines)	Hearing loss
Babich DR, Bauer ER [2006], Underground bituminous coal mine noise surveys, Mining Engineering Magazine, 2006. (refereed)	2006	Publication	Hearing loss
Peterson JS, Kovalchik PG, Matetic RJ [2007]. Noise source identification on a roof bolting machine using a beamforming technique, Society for Mining, Metallurgy, and Exploration, Inc., 2007 SME Conference	2007	Publication	Hearing loss
Peterson JS [2007]. Estimating sound power radiated by surfaces on a roof bolting machine using vibration measurements. In: Proceedings of NOISE-CON 2007	2007	Publication	Hearing loss
Peterson JS [2008]. Evaluation of engineering noise controls for a roof bolting machine. In: Proceedings of NOISE-CON 2008	2008	Publication	Hearing loss
MSHA [2008]. Information Bulletin P04-18, Roof bolting machine engineering controls, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls 30 CFR Part 62	2008	Standards	Hearing loss
Video on implementing and the development of roof bolting machines noise controls, 2008	2008	Video	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss

Title	Year	Output Type	Strategic Goal
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss
Guidelines on effective engineering noise controls for roof bolting machines - Web content	2006	Web document	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Continuous Mining Machines - Jacketed Tail Roller

Background

Engineering noise controls are being developed to reduce the noise generated by continuous mining machines, which produce some of the highest sound levels in underground mining. The project involves the development of a jacketed tail roller, which is a roller at the tail end of the conveyor of the machine. By encasing this roller in hard, durable plastic, the conveyor chain and coal being transported will be contacting a metal roller (for durability) constrained by polyurethane material, which should reduce the noise generated by the process. It is hoped the development of this product will reduce the sound level at the operator's position by 3 dB(A).



Jacketed tail roller installed on a continuous mining machine

Use of a jacketed tail roller may be applicable to other underground mining equipment such as loaders and shuttle cars and could reduce the amount of noise to which the operators of these types of equipment are exposed. This project complements the work done to introduce coated flight bars on conveying systems.

Potential Outcome

To raise industry awareness of the engineering noise controls developed through this work, research results will be published in a trade magazine article and presented at industry briefings concerning noise exposure in the mining industry. It is anticipated that this research could lead to a noise reduction of up to 10 dB(A) at the operator position on the continuous miner's conveying systems. By reducing the noise generated by the machines by this amount, 50% of the continuous mining machine operators and 100% of the loader and shuttle car operators could be working in an environment where noise levels are below the MSHA permissible exposure limit.

Outputs

5 Planned or completed outputs

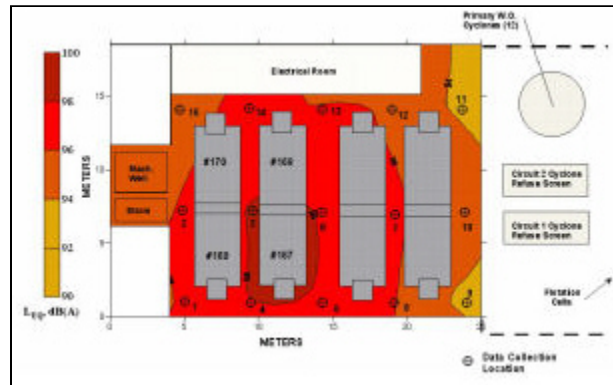
Title	Year	Output Type	Strategic Goal
Jurovcik P [2007]. Underground evaluation of a jacketed tail roller as an effective engineering noise control for continuous mining machines, Society for Mining, Metallurgy, and Exploration, Inc., 2007 SME Conference	2007	Publication	Hearing loss
MSHA [2007]. Jacketed tail roller - Program Information Bulletin P04-18 [2007], "Technologically Achievable, Administratively Achievable, and Promising Noise Controls," 30 CFR Part 62	2007	Standards	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
Jurovcik P [2008]. Evaluation of a jacketed tail roller as an effective engineering noise control for continuous mining machines. In: Proceedings of NOISE-CON 2008: Institute of Noise Control Engineering of the USA	2008	Publication	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Horizontal Vibrating Screens

Background

Engineering noise controls are being developed and tested to reduce the noise generated by horizontal vibrating screens used in coal preparation plants. These screens are among the equipment used in preparation plants that generate the highest sound levels. A NIOSH cross-sectional survey project indicated that 20 out of 46 surveyed coal preparation plant workers (43.5%) had noise exposures exceeding MSHA's permissible exposure level (PEL). Based on the cross-sectional survey and MSHA data, it appears that more than 3,400 coal preparation plant workers are overexposed to noise across the country.



Sound levels around 8 horizontal vibrating screens

NIOSH is working with mining companies and vibrating screen manufacturers to evaluate various controls for reducing noise related to the screens. Measurements taken by NIOSH showed that the sound levels around a group of eight horizontal vibrating screens ranged from 94 to 98 dB(A). The goal of this project is to develop engineering noise controls that will reduce sound levels by 10 dB(A).

Potential Outcome

Research on engineering noise controls for horizontal vibrating screens will be completed in 2008. To raise industry awareness of the engineering noise controls developed, results will be disseminated through publications in journals and trade magazines and also presentations at technical conferences and industry briefings related to noise exposure in the mining industry. In addition, an informational DVD/CD that summarizes the development and safety benefits of the developed engineering noise controls will be produced. This DVD/CD will target vibrating screen manufacturers and industries that use vibrating screens. This work has the potential to eliminate noise overexposures for approximately 3,400 coal preparation plant workers. It is anticipated that 43% of the coal preparation plant workers could be affected by 2009.

Outputs

15 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Estimated Sound Power Radiated by Surfaces on a Continuous Miner Tail Section Using Vibration Measurements Yantek-DS NOISE-CON 2003. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-9	2003	Publication	Hearing loss
Noise and Vibration Reduction of a Vibrating Screen Yantek-DS; Jurovcik-P; Bauer-ER SME Preprint No. 05-71, 2005 SME Conference, Salt Lake City, Utah, 2005; :1-13	2005	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Yantek DS [2006]. Noise source identification on horizontal vibrating screens using a beamforming technique, Society for Mining, Metallurgy, and Exploration, Inc., 2006 SME Conference	2006	Publication	Hearing loss
Yantek DS [2008]. Evaluation of engineering noise controls for horizontal vibrating screens. Proceedings of NOISE-CON 2008: Institute of Noise Control Engineering of the USA	2008	Publication	Hearing loss
Yantek DS [2008]. NIOSH-RI, Summarizing the results related to engineering noise controls for horizontal vibrating screens	2008	Publication	Hearing loss
MSHA [2009]. Information Bulletin P04-18 Vibrating screen engineering control, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls 30 CFR Part 62	2009	Standards	Hearing loss
Video on implementing and development of vibrating screen noise controls, 2009	2009	Video	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss
Guidelines on effective engineering noise controls for horizontal vibrating screens - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Yantek DS [2007]. Estimating sound power radiated by horizontal vibrating screens, Proceedings of NOISE-CON 2007, In: Institute of Noise Control Engineering of the USA	2007	Publication	Hearing loss
Guidelines on effective engineering noise controls for horizontal vibrating screens - Web content	2008	Web document	Hearing loss

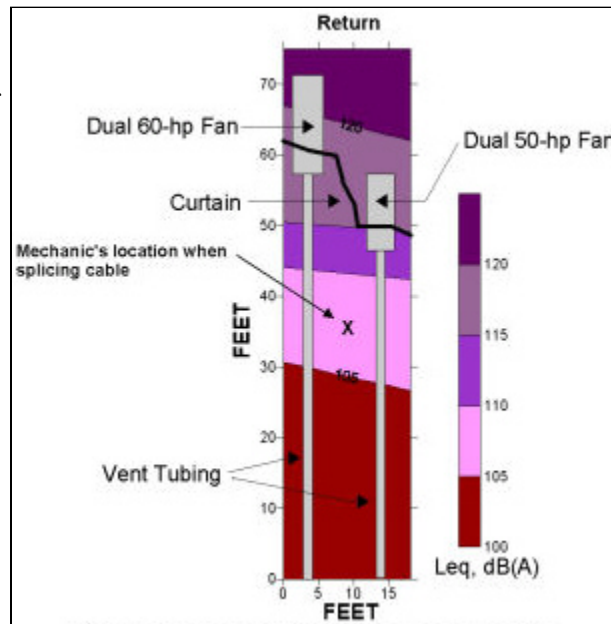
Potential Intermediate Outcome for Hearing Loss

Administrative Computer Program

Background

Noise exposure data recently collected by NIOSH researchers during project surveys in the mining industry indicate that nearly 50% of the workers were exposed to noise levels above 90 dB(A), and some exposures were nearly six times the permissible exposure level (PEL). Information on the MSHA Web site notes that there are approximately 223,000 employees in the mining industry across the United States. If the rate of overexposure is extrapolated (at the 50% overexposure rate) across all employees in mining, more than 111,000 workers across the country would be overexposed to noise.

The long-term objective of this study is to obtain multi-shift data on worker noise exposure and equipment noise levels in order to develop an up-to-date comprehensive profile of the amount of noise the mining population is exposed to as a function of equipment and activity-specific operations. Specific aims are to collect cross-sectional noise exposure information by occupation and equipment noise level, and develop the source and/or dose relationship based on this information. From these data, appropriate noise controls can be selected for occupations routinely overexposed to noise.



Sound profile map of auxiliary ventilation fans

A computer program is currently being developed that will assist mine operators in analyzing a worker's noise exposure and then selecting an appropriate administrative control. This program will simplify the record-keeping associated with selecting administrative controls, as well as allowing observational information (task observations/time studies) to be input more easily. The program will indicate what tasks are responsible for most of a worker's exposure and suggest appropriate controls. The resulting impact will be the reduction of noise exposures because of an improved administrative controls selection process.

Potential Outcome

All workers in the mining industry could be affected by this research. Once completed, the program will be validated through testing in several mines and then communicated to the mining industry via partnership meetings, mining journals, NIOSH publications, seminars, and conferences. It is anticipated that the impacts of this research will begin in 2006 with the initial release of the administrative control computer program.

Outputs

19 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Cross-Sectional Survey of Noise Exposure in the Mining Industry Bauer-ER; Kohler-JL Proc 31st Annual Institute of Mining Health, Safety and Research, Aug 27-30, 2000, Roanoke, VA, Bockosh-G, Karmis-M, Langton-J, McCarter-MK, Rowe-B, eds. Virginia Tech 2000 Aug; :17-30	2000	Publication	Hearing loss
Noise Exposure in Longwall Mining and Engineering Controls Research Bauer-ER; Podobinsk-DJ; Reeve- ER In: Proceedings of Longwall USA International Exhibition and Conference, June 13-15, Pittsburgh, PA, Intertec Publishing Corp.; :51-69	2001	Publication	Hearing loss
Worker Exposure and Equipment Noise in Large Surface Coal Mines Bauer-ER; Babich-DR SME preprint 03-051. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :1-6	2003	Publication	Hearing loss
Administrative Controls for Reducing Worker Noise Exposures Bauer-ER; Babich-DR SME preprint 04-09. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; :1-9	2004	Publication	Hearing loss
Worker Exposure and Equipment Noise in Large Surface Coal Mines Bauer-ER; Babich-DR Min Eng 56(4), 2004; :49-54	2004	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Testing and Evaluation of an Engineering Noise Control on a Longwall Stageloader Bauer-ER; Reeves-ER; Durr-TM; Zuchelli-DR; Armour-D SME preprint 05-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; :1-12	2005	Publication	Hearing loss
Noise and Vibration Reduction of a Vibrating Screen Yantek-DS; Jurovcik-P; Bauer-ER SME Preprint No. 05-71, 2005 SME Conference, Salt Lake City, Utah, 2005; :1-13	2005	Publication	Hearing loss
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/compliance/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/compliance/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Bauer ER, Babich DR, Viperman JS [2006]. Equipment noise and worker exposure in the coal mining industry. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No., IC, In review.	2006	Publication	Hearing loss
Viperman JS, Bauer ER, Babich DR [2006]. Survey of noise in coal preparation plants. Journal of Acoustical Society of America, Submitted to Journal. (refereed)	2006	Publication	Hearing loss
Bauer ER, Babich DR [2006]. Administrative controls for reducing worker noise exposures. Trans Soc Min Eng, Vol. 318. (refereed)	2006	Publication	Hearing loss

Title	Year	Output Type	Strategic Goal
Mining Engineering Journal article: Noise Surveys at Surface and Underground Stone Mines, 2007. (refereed)	2007	Publication	Hearing loss
Society of Mining Engineering 2008 Annual Meeting and Exhibit: Sand and Gravel Noise Surveys, 2008	2008	Publication	Hearing loss
Journal of Acoustical Society of America: Nonmetal Mine Noise Surveys, 2009. (refereed)	2009	Publication	Hearing loss
Software and users manual for assisting mine operators to select, implement, and evaluate administrative controls, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Pittsburgh, PA: DHHS (NIOSH IC) Publication No., 2007	2007	Software	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Continuous Mining Machines - Dust Collector Fan

Background

NIOSH is working with the Pennsylvania State University and Joy Mining Machinery to develop engineering noise controls to reduce noise generated by continuous mining machines. The research involves the development of noise treatments for a dust collector fan, which is a vane axial fan located inside the continuous mining machine. The noise treatments applied to the fan were:

1. moving the turning vanes downstream,
2. changing the shape of the leading edges of the turning vanes from straight and radial,
3. extending the perforations and outside adsorptive layer to cover the entire fan housing,
4. adding an extension with an absorptive layer on the onside to the fan discharge, and
5. replacing the rotor with unevenly spaced blades with a rotor with evenly spaced blades



A dust collector fan with noise treatments installed

The effort resulted in an overall A-weighted sound power level reduction of 5 dB with only a 4 % reduction in the volume flow velocity through the dust collector. This research compliments the work performed on coated flight bars and the jacketed tail roller on continuous mining machine conveying systems.

Potential Outcome

The engineering noise controls developed as a result of this research, along with the prior research on the continuous miner's conveying systems (coated flight bars and jacketed tail roller), could lead to an overall noise reduction of up to 10 to 12 dB(A) at the operator position of the continuous mining machine. With these controls properly installed, it could be anticipated that 90% of the operators of continuous mining machines noise exposure will fall below MSHA's permissible exposure limit. To raise industry awareness of the engineering noise controls developed through this work, research results will be published in trade magazine articles and presented at industry briefings concerning noise exposure in the mining industry. The effects of the engineering controls are expected to begin in 2006, when underground test results are finalized and published.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Reduction of Noise Emissions from the Vane Axial Fan in a Dust Collector in a Continuous Miner Carter-BA; Burroughs-CB The Pennsylvania State University Applied Research Laboratory, Final Technical Report 04-01 under Contract No. 200-2001-08005, July 30, 2004	2004	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
MSHA [2007]. Noise treatments for a dust collector fan - Program Information Bulletin P04-18 [2007], "Technologically Achievable, Administratively Achievable, and Promising Noise Controls," 30 CFR Part 62	2007	Standards	Hearing loss

Potential Intermediate Outcome for Cumulative Injuries

Improving Mobile Equipment Operator Ergonomics

Background

There are over half a million operators of heavy equipment (i.e., dozers, loaders, haul trucks, etc.) in mining and construction in the United States, and this number is expected to increase. Factors in the work environment, such as whole body vibration, awkward postural requirements (including static sitting), repetitive motions, poor seat design, poorly designed cabs or controls, and a host of other ergonomics issues, have the potential to cause injury and expose operators to the risk of developing musculoskeletal disorders. In mining, MSHA data show that between 1999 and 2003, 4,079 accidents in the surface mining industry were classified as back injuries and contributed to the nearly 173,000 lost or restricted work days (an average of 42 days lost or restricted per accident). Truck drivers, dozer operators, and front-end loader operators alone accounted for over one-third of these injuries.



Heavy haulage equipment

Potential Outcome

Potential impacts include the development of engineering interventions to alleviate back injuries among operators of mobile equipment. Another potential impact is increased awareness of the need to address ergonomically functional cab designs before equipment is modified. For example, changes made to a mobile equipment operator's cab to reduce noise exposure may produce unintended compromises to the operator's posture or line of sight. Increased awareness would avoid these well-intended, but sometimes counterproductive efforts.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Tying Acceleration and GPS Location Information Together To Create a Mine Management Tool Miller-RE; Bowman-P; Walden-J; Rhoades-S; Gibbs-R SME Annual Meeting, March 1-3, 1999, Denver, Colorado; Preprint 99-118; 4 pp	1999	Publication	Cumulative injuries; Traumatic injuries
Acceleration and GPS Data Monitor Truck-Haulage Jolts Miller-RE; Boman-P; Walden-J; Rhoades-S; Gibbs-R Min Eng, 52(8):20-22	2000	Publication	Cumulative injuries; Traumatic injuries
An Ergonomic Evaluation of Excavating Operations: A Pilot Study Kittusamy-NK; Buchholz-B Applied Occupational and Environmental Hygiene, vol. 16, no. 7, 2001; :723-726	2001	Publication	Cumulative injuries
Ergonomic Risk Factors: a Study of Heavy Earthmoving Machinery Operators Kittusamy-NK Professional Safety: Journal of American Society of Safety Engineers, 2002 Oct	2002	Publication	Cumulative injuries
Self-Reported Musculoskeletal Symptoms Among Operators of Heavy Construction Equipment Kittusamy-NK In: Ergonomics in the Digital Age: Proceedings of the XVth Triennial Congress of the International Ergonomics Association and 7th Joint Conference of Ergonomics Society of Korea/Japan Ergonomics Society (Seoul, Korea, Aug. 24-29, 2003). Seoul, Korea: Ergonomics Society of Korea, 2003 Aug	2003	Publication	Cumulative injuries
A Checklist for Evaluating Cab Design of Construction Equipment Kittusamy-NK Applied Occupational and Environmental Hygiene 18, 2003; :721-723	2003	Publication	Cumulative injuries
Assessment of Ergonomic Risk Factors Among Operators of Heavy Earthmoving Machinery Kittusamy-NK In: Proceedings of the 2003 ASSE Professional Development Conference (Denver, CO, June 22-26, 2003), American Society of Safety Engineers, 2003 Jun; :11 pp	2003	Publication	Cumulative injuries
A Systematic Comparison of Different Seats on Shuttle Cars Used in Underground Coal Mines Kittusamy-NK; Mayton-AG; Jobes-CC; Ambrose-DH In: Proceedings of Inter-Noise 2003, the 32nd International Congress and Exposition on Noise Control Engineering (Seogwipo, Korea, Aug. 25-28, 2003). 2003 Aug; :2025-2032	2003	Publication	Cumulative injuries; Traumatic injuries
Comparison of Jolting and Jarring in a Newer and Older Dozer at a Highway Construction Site Kittusamy-NK; Miller-RE In: Ergonomics in the Digital Age: Proceedings of the XVth Triennial Congress of the International Ergonomics Association and the 7th Joint Conference of the Ergonomics Society of Korea/Japan Ergonomics Society. Seoul, Korea: Ergonomics Society of Korea, 2003; :1-3	2003	Publication	Cumulative injuries; Traumatic injuries
Whole-Body Vibration and Postural Stress among Operators of Construction Equipment: A Literature Review Kittusamy-NK; Buchholz-B Journal of Safety Research 2004, vol. 35, no. 3, 2004; :255-261	2004	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Age Awareness Training Modules

Background

On average, employees working in mining are older than those working in other industries. It is projected that the median age of U.S. mine workers will continue to increase throughout the next decade. Changes in physical and cognitive abilities that accompany the normal aging process may be accelerated in mine workers as compared to other industries and have the potential to increase the risk of injury. For instance, changes in vision may affect a person's ability to perceive a warning signs and changes in strength may place a person at risk for injury. A need exists for general training about the normal changes that accompany aging and ways that worksites can mediate those changes. In keeping with the Steps to a Healthier U.S. Workforce (STEPS) approach, this training combines occupational injury prevention with health promotion by combining recommendations for both worksite modifications and improvements in individual behaviors.



Typical underground mining crew

This program includes management training, a seven-module training program (with a newsletter and safety talk guide for each module), and an instructor's guide. The training modules included in the Age Awareness Training are designed to be given individually in 10-minute safety talks or combined in a longer training session. The newsletter included in each training module could also be disseminated to an employee through company newsletters or other mailings sent to employees' homes. The Age Awareness Training has the potential to reach management, employees, and even the families of employees.

Potential Outcome

Potential impacts from this project by 2008 are:

1. Increased awareness of normal age-related changes and ways to mediate them through worksite changes and improvements in individual behaviors can lead to reductions in injuries, and
2. Reductions in injuries and improved lifestyle behaviors that will lead to decreased medical costs. Such decreases could be realized either through costs associated with worker's compensation or, in the case of self-insured companies, regular medical costs.

These training modules will be piloted at several mines and then presented at both mining and safety conferences. MSHA is interested in giving this training to its inspectors. The training will be available on a CD or downloadable through NIOSH Web pages. In addition, this training might be used as a prototype method and applied to other industries, such as agriculture and construction.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Aging and Musculoskeletal Injuries in the US Mining Industry - Journal of Safety Research	2006	Publication	Cumulative injuries
Age Awareness Training for Miners: A Holistic Approach to Injury Reduction - peer-reviewed SME Journal	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Slips and Falls Research

Background

Across the nation, falls account for 12.5% of all fatal occupational injuries and 19.9% of all nonfatal occupational injuries involving days away from work. The annual direct cost of fall-related occupational injuries in the United States has been estimated at \$6 billion, and the burden of slip-, trip-, and fall-related occupational injuries has been estimated as ranging from 20% to 40 % of all disabling occupational injuries. Injury surveillance in mining parallels national statistics and indicates that falls account for a large number of incidents in all mine workers, plus an increased risk of injury from slips



Operator egressing from loader

and falls exists for older miners. To respond to the need for better methods of injury prevention, two projects have begun: (1) a project on tread design that will evaluate the coefficient of friction for different treads and materials on different mining surfaces and (2) a study on methods to evaluate ingress/egress systems and suggest techniques to reduce the risk of injury from getting on and off equipment. Our goal is to provide employees with better protection against a potential slip or fall while they are either walking or getting on or off equipment. This approach involves the use of improved personal protective equipment as well as improved human/machine interfaces and commercialization opportunities. These recommendations will address the abilities of an age-diverse workforce.

Potential Outcome

By 2009, recommendations for tread designs and sole materials for miner boots and safer ingress/egress systems will lead to a reduction in injuries from slips and falls related to walking and getting on and off equipment (this project does not address falls from heights). In the case of ingress/egress, the recommendations may include maximum distances for the first step, for the reach to a handrail, and/or the depth of a platform or step. A reduction in injuries in these areas will lead to decreased financial and personal burdens. In addition, since slips and falls are a universal problem, recommendations for better tread designs and materials for miners in certain environments and better ingress/egress systems may also benefit workers in construction and agriculture. Knowledge gained from these studies will be disseminated in the form of guidelines, design specifications, training modules, and evaluation tools passed on at conferences, workshops, and industry-wide briefings.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Guidelines on designing for ingress/egress from equipment - International Journal of Ergonomics	2007	Publication (guidelines)	Cumulative injuries
Development of a Methodology for Tread Study - to be submitted to Human Factors	2007	Publication	Cumulative injuries
Evaluation of Different Boot Tread Designs in Different Environments to Reduce the Risk of Slips and Fall in the Mining Industry - to be submitted to Ergonomics	2007	Publication	Cumulative injuries
Guidelines for the Selection of Tread Design and Materials for Mine Worker Boots - peer-reviewed SME journal	2007	Publication	Cumulative injuries
Investigating Criteria for the Evaluation of Ingress/Egress Systems on Wheel Loaders - Conference proceedings, International Ergonomics Association Meeting (Maastricht, Netherlands).	2006	Publication	Cumulative injuries
Training Materials on Preventing Injuries from Operating Mobile Equipment: Focus on Ingress/Egress and Vibration - Industrial Minerals Association of North America workshop (Pittsburgh, PA)	2006	Training	Cumulative injuries
Development of Criteria for the Evaluation of Ingress/Egress Systems for the Risk of Injuries - Journal of Industrial Ergonomics	2007	Publication	Cumulative injuries
Guidelines for tread design	2007	Video	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Knee Injury Prevention

Background

As higher-seam coal mines are increasing mined out, companies are turning to low-seam options as ways to meet the demand for coal. Seam height in low-seam mines can range from 36 to 44 inches, requiring miners to spend a large percentage of their days either crawling or working in a kneeling position. Because of these nonneutral restricted postures, mine workers experience knee pain and injury earlier and to a greater degree than would be experienced in nonmining environments.



Roof bolting in low coal

Many mine companies consider low-seam coal mining to be a young man's game! To reduce the risk of knee injury, a multi-faceted research project has been started that includes an epidemiology study, task analyses of different occupations in low-seam mining, the creation of a biomechanical model of the knee, and a healthy knee training module. These tasks all contribute to the goal of recommending improved designs for work methods as well as the development of personal protective equipment. A comprehensive study on ways to reduce knee injuries in coal mining has never before been initiated.

Potential Outcome

By 2009, this study will lead to the reduction of knee injuries in coal miners, so that coal miners can work longer in low-seam operations. In addition, analyses using the biomechanical model of the knee may lead to the reduction of knee injuries in people working in other occupations. The development of new knee pad designs will contribute to the reduction of knee injuries in mining. All these reductions in injuries will decrease the personal and financial burden of these injuries. Knowledge gained as a result of this study will be disseminated in the form of guidelines, training programs, recommendations for better work practices, and recommendations for improved knee pad designs. These results will be disseminated through mining and safety conferences, as well as through MSHA. Success of this multi-faceted, skills-leveraging approach that utilizes the talent of people working in industry, government, and academia may inspire others to use the same approach to answer their research questions.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
An Epidemiological Study of Knee Injuries in Low Seam Coal Mining - to be submitted to SME (peer-reviewed)	2007	Publication	Cumulative injuries
The Development of a Healthy Knee Module for Low Seam Coal Miners - Journal of Safety Research	2006	Publication	Cumulative injuries
The Development of a Finite Element Biomechanical Model of the Knee - model completed and will be submitted to Clinical Biomechanics journal	2007	Publication	Cumulative injuries
Evaluating the Risk of Knee Injury Using a Finite Element Model of the Knee - Occupational Biomechanics journal (peer-reviewed)	2007	Publication	Cumulative injuries
The Evaluation of New Knee Pad Designs to Prevent Injuries in Low Seam Coal Miners - to be submitted to peer-reviewed Ergonomics and SME journals	2007	Publication	Cumulative injuries
Guidelines for reducing the risk of injury while working in low seam coal mines - peer-reviewed SME journal	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Improved Risk Assessment for Low Back Disorders in Mining

Background

Extensive evidence exists that work-related low back disorders affect mine workers to a greater degree than workers in other industries. Studies have shown that miners experience more disability from back pain, more disk degeneration, and a higher rate of worker's compensation claims in comparison to other industrial populations. Low back disorders are consistently the single leading cause of lost-time injuries in the U.S. mining industry. The high incidence of low back disorders in mining is certainly a reflection of the physically demanding nature of mining jobs; however, the mining environment often imposes additional biomechanical demands by forcing workers to adopt restricted postures (such as stooping or kneeling) for prolonged periods when working. In terms of low back stress, the stooping posture (which involves flexion of the torso) is of particular concern and has been associated with increased risk for low back disorders in epidemiologic studies.



Reducing low back disorders for mine workers

Many scientists believe that back pain is the result of a cumulative process of damage to spinal tissues caused by repetitive loading. However, few studies have examined the tolerance of spinal tissues to repetitive loading, and none have examined how increased spinal loads when lifting in torso flexion affect how quickly spinal tissues fail when they are loaded repetitively. Accordingly, a cadaver study involving 54 spine motion segments (two vertebrae and the intervening disc) was performed to simulate compressive and shear forces during simulated lifting of a 9-kg load in three torso flexion postures (neutral, partial flexion, full flexion). The number of cycles to specimen failure was used as the primary dependent measure. Results demonstrated that the number of cycles to fatigue failure were dramatically reduced in simulated flexed lifting compared to lifting in more upright postures. The average number of cycles to failure for upright, partial flexion, and full flexion were 8846, 4549, and 1485, respectively. The more rapid development of spinal tissue failure in flexed lifting may help explain the high incidence of low back disorders in coal mining (where flexed lifting is prevalent), but also have great relevance toward development of effective prevention measures. In particular, these results suggest that exposure to flexed lifting may be a key risk in low back disorders and that minimizing such exposure may be quite effective in reducing low back disorders in mining.

Potential Outcome

Results of this study and other important recent research findings related to low back pain are currently being used in the development of an "evidence-based" low back exposure assessment tool for the mining industry. The specific aims of this project are to develop guidelines and a tool for a paper-and-pencil low back exposure assessment that (1) is applicable to the unique physical stresses encountered in the mining environment, (2) takes advantage of recent research findings on potential injury pathways to the low back, and (3) is easy to use and administer. This tool is currently being pilot tested at a cooperating minesite. If this approach proves ultimately successful in developing a model that can predict risks of low back disorder at mining worksites, by 2009 the proposed exposure assessment tool is likely to have a remarkable impact on the design and evaluation of work tasks in the mining industry.

Outputs

17 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Physical Limitations and Musculoskeletal Complaints Associated With Work in Unusual or Restricted Postures: A Literature Review Gallagher-S J Saf Res 2005 Jan; 36(1):51-61	2005	Publication	Cumulative injuries
Torso Flexion Loads and Fatigue Failure Mode of Human Lumbosacral Motion Segments Gallagher-S; Marras-WS; Litsky-AS; Burr-D Spine 30(20)	2005	Publication	Cumulative injuries
Validity and Reliability of Sincerity Test for Dynamic Trunk Motions Ferguson-SA; Gallagher-S; Marras-WS Disability and Rehabilitation 25(4), 2003	2003	Publication	Cumulative injuries
Effects of Posture on Dynamic Back Loading During a Cable Lifting Task Gallagher-S; Marras-WS; Davis-KG; Kovacs-K Ergonomics, 2002 45(5), 2002; :380-398	2002	Publication	Cumulative injuries
The Effects of Restricted Workspace on Lumbar Spine Loading Gallagher-S; Hamrick-CA; Cornelius-KM; Redfern-MS Occupational Ergonomics 2(4), 2001; :201-213	2001	Publication	Cumulative injuries
Trunk Extension Strength and Muscle Activity in Standing and Kneeling Postures Gallagher-S Spine 22(16), 1997 Aug; :1864-1872	1997	Publication	Cumulative injuries
Dynamic Biomechanical Modeling of Symmetric and Asymmetric Lifting Tasks in Restricted Postures Gallagher-S; Hamrick-CA; Love-AC; Marras-WS Ergonomics 37(8): 1289-1310	1994	Publication	Cumulative injuries
Acceptable Workloads for Three Common Mining Materials Gallagher-S; Hamrick-CA Ergonomics 35(9):1013-1031	1992	Publication	Cumulative injuries
The Kyphotic Lumbar Spine: Issues in the Analysis of Stresses in Stooped Lifting Gallagher-S; Hamrick-CA International Journal of Industrial Ergonomics 8(1):33-47	1991	Publication	Cumulative injuries
Acceptable Weights and Physiologic Costs of Performing Combined Manual Handling Tasks in Restricted Postures Gallagher-S Ergonomics 34(7): 935-952	1991	Publication	Cumulative injuries
Lifting Under Four Restrictive Roof Heights: Psychophysical, Physiological, and Biomechanical Effects of Lifting in Stooped and Kneeling Postures Gallagher-S; Unger-RL Applied Ergonomics, 21(3): 237-245	1990	Publication	Cumulative injuries
Recommendations for Handling Materials in Low-seam Coal Mines Gallagher-S Applied Industrial Hygiene, 4(6): F8 BF12	1989	Publication	Cumulative injuries
Lifting in Stooped and Kneeling Postures: Effects on Lifting Capacity, Metabolic Cost, and Electromyography of Eight Trunk Muscles Gallagher-S; Marras-WS; Bobick-TG International Journal of Industrial Ergonomics, 3(1): 65-76	1988	Publication	Cumulative injuries
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., in press. Factors Associated with Specific Failure Modes in Fatigue Testing of Human Lumbosacral Motion Segments, accepted for publication in the journal Clinical Biomechanics	2006	Publication	Cumulative injuries
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., in review. The influence of bone mineral content and specimen morphology on the risk of fatigue failure of lumbar motion segments, European Spine Journal	2006	Publication	Cumulative injuries
Assessment tool for low-back exposure - Journal of Applied Ergonomics	2008	Publication	Cumulative injuries

Title	Year	Output Type	Strategic Goal
Benefits of using the Low Back Assessment tool and its effectiveness in diagnosing problem areas. To be submitted to Occupational Ergonomics and for a NIOSH Informational Circular	2007	Publication	Cumulative injuries

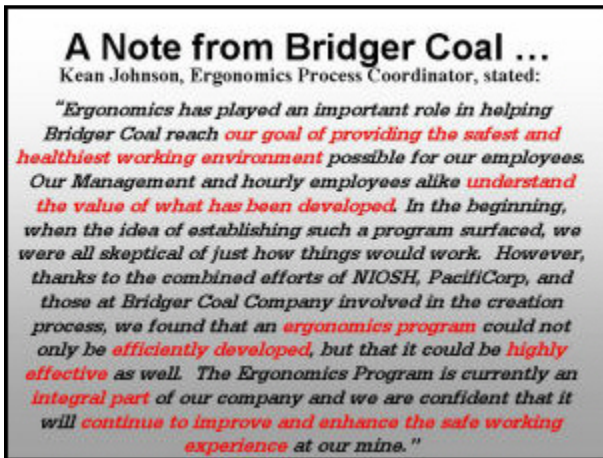
Potential Intermediate Outcome for Cumulative Injuries

Ergonomic Processes

Implementation/Integration and Process Metric

Background

Musculoskeletal injuries have long been identified as a significant and costly problem for the mining industry. Research has shown that establishment of a process to identify ergonomic risk factors, implement solutions to reduce injury, and determine the effectiveness of these solutions is the best way to reduce injury and illness and their related costs, as well as to improve work performance and quality. The ergonomics literature contains numerous reports of ergonomic programs that successfully reduced work-related injury and illness. However, the documented evidence for dynamic work environments such as mining, construction, and agriculture describes only time-limited or quick-fix actions. Time-limited actions address a specific problem at a certain time and often remain an isolated event with time-limited results. In addition, few scientific evaluations of ergonomics programs and/or processes have been developed. Although guidelines regarding basic process elements exist, no scientific study that documents specific tasks and resources necessary for implementation has been conducted.



A note from Bridger Coal

Processes will be implemented at two sites, the Badger Mining Co. and Vulcan Materials. Badger has provided training to all its employees at its two mines in Wisconsin, completed a baseline assessment of risk factor exposures, and is in the process of integrating ergonomics with its behavior-based safety system. For the Badger process, a risk factor checklist was written for the baseline assessment, observer training was developed to improve the capabilities of the observers to reduce exposures, and an observation form was created for observers to document their observations and solutions. Vulcan Materials is in the planning stage of how best to integrate ergonomics into its safety program.

In addition to working with Badger and Vulcan, partnerships will be formed with trade associations to promote the application of ergonomics to their memberships. The partnerships will provide a mechanism to reach more companies than what NIOSH researchers alone could do. To date, one partnership has been established with the Industrial Minerals Association-North America. Other partnerships will be initiated in 2006 with the National Stone, Sand and Gravel Association and the National Mining Association. To develop a process metric, a focus group composed of professional ergonomists will be asked to develop a rating scheme that will be used to rate the ergonomics processes of participating companies and

identify a list of tasks relevant to process implementation. The rating scheme and task list will then be used by companies with histories of having implemented successful ergonomics processes. The information gained from these companies will be validated through external evaluations.

Potential Outcome

The primary benefits of this work will be to gain a better understanding of the specific activities that contribute significantly to the development of effective processes and provide evidence to the mining industry that well-developed ergonomics processes are proactive mechanisms that greatly reduce risks for musculoskeletal disorders. Specifically, as more mining companies implement processes, risks for musculoskeletal disorders will be reduced by 2010, and improvements in health and safety for the worker and workplace will be put into place. Knowledge gained will be disseminated to the mining industry through trade association partnerships, industry-oriented publications, professional research journals, NIOSH publications, industry briefings, workshops, and conferences.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Using Ergonomics to Enhance Safety and Health in the U.S. Mining Industry Steiner-L; Torma-Krajewski-J; Schwerha-D 31st International Conference of Safety in Mines Research Institutes, 2-5 October 2005, Brisbane, Queensland, Australia. Redbank, Queensland, Australia: Safety in Mines Testing and Research Station (Simtars), 2005 Oct; :106-111	2005	Publication	Cumulative injuries
Simple solutions ergonomics publication for underground mining - NIOSH IC	2006	Publication	Cumulative injuries
Simple solutions ergonomics publication for surface mining - NIOSH IC	2009	Publication	Cumulative injuries
Torma-Krajewski, J., Steiner, L., Lewis, P., Gust, P., Johnson, K. Ergonomics and Mining: Charting a Path to a Safer Workplace, NIOSH Information Circular	2006	Publication	Cumulative injuries
Torma-Krajewski, J., Steiner, L., Wiehagen, W., Unger, R., Lewis, P., Gust, P., Johnson, K. Ergonomics and Mining: Oil and Water or Cream and Sugar. Submitted to the International Journal of Industrial Ergonomics. In review, peer reviewed	2006	Publication	Cumulative injuries
Designing with a Purpose: Equipment Issues in Mining - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Implementation of an ergonomics process by the Badger Mining Company - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Implementation of an ergonomics process by the Vulcan Mining Company - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Development of a metric that can be used to evaluate the effectiveness of ergonomics processes. To be submitted to Applied Ergonomics	2007	Publication	Cumulative injuries
Developing a metric for defining and evaluating process element activities and the effects of these activities on MSD incident rates and other outcome measures. To be submitted to Applied Ergonomics	2007	Publication	Cumulative injuries

Falkirk Mine Dragline Workstations: The Falkirk Mining Co. operates several draglines equipped with adjustable workstations, including adjustable joysticks. Operators were surveyed to obtain user data on the effectiveness of the adjustments in improving comfort. Videos of the operators were obtained to evaluate postures and adjustments made prior to operating the dragline.

Potential Outcome

The objective of this intervention is to develop recommendations on how to improve workstations for draglines and other types of equipment where operators are required to work for long periods of time. By 2010, the improvements will allow workers to perform their jobs with less exposure to risk factors, result in fewer musculoskeletal disorders, and improve comfort and efficiency. Materials, such as videos and posters, will be developed to assist with the transfer of knowledge gained during these tasks. The prototype workstation will also continue to be available to the industry at Southern Illinois University for training purposes. Knowledge gained will be disseminated to the mining industry through trade association partnerships, industry-oriented publications, professional research journals, NIOSH publications, workshops, and conferences.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Ready-Adjust-Operate, NIOSH Dragline Workstation <small>Lewis-P; Rossi-EW 2005 Video</small>	2005	Video	Cumulative injuries
Effectiveness of Adjustability in Dragline Workstations - SME journal or Applied Ergonomics (peer reviewed)	2007	Publication	Cumulative injuries
Design Criteria for Dragline Workstations - NIOSH Information Circular	2007	Publication	Cumulative injuries
Video production on Mobile Equipment Operator Workstations	2007	Video	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Reducing Injuries during Bagging Tasks

Background

Packaging products in bags of all sizes is a common way of transporting the product to the end user. Bags used in the mining industry, for the most part, fit in two categories: bulk bags and small bags. Bulk bags, also known as, flexible intermediate bulk containers (FIBC) or super sacks, are used in many industries, including pharmaceuticals, agriculture, construction, and mining. Within the mining industry, there is a concern about injuries and exposures during bagging operations. One of our cooperating minesites recently had two employees sustain shoulder injuries during bagging tasks. The ergonomic risk



Tying a bulk bag

factors in bulk bagging operations occur primarily when the operator opens and prepares the bag for filling and again when the bag is being closed. Both the opening and closing of the bag may introduce musculoskeletal injuries to the operator's low back, shoulders, arms, neck, wrists, and hands. This task requires forceful work and awkward postures due to the size of the bag and the current design of the bags. Small bags (usually carrying 100 pounds or less) are also a common means of packaging and transporting mined industrial minerals. Depending on the level of automation and the work practices at a given site, a number of possible risk factors need to be addressed, such as manual lifting of the bags for weighing or manually stacking bags on a pallet. The most common risk factors associated with small bag operations will be identified and investigated to develop ergonomic interventions to reduce and/or eliminate these factors. The objective of this study is to identify the best design features for bagging tasks and thus reduce exposure of operators to ergonomic risk factors.

Potential Outcome

By 2008, the research on bagging will lead to the development of recommendations for purchasing bags and work practices for operators to reduce injury risk during bulk bagging operations. Improving this common work task will provide a safer work environment. Results from this task will be provided to industry in a guidance document and mining journal publications and will include an overview of bagging operations, descriptions of bulk bag design characteristics, work methods used in bagging, exposures to ergonomic risk factors, and appropriate control methods for reducing exposures. Because bulk and small bagging operations are part of several industries in addition to mining, the results of this project will be applicable to these industries as well.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Bag design characteristics and the reduction of ergonomic risk factors - Journal of Applied Ergonomics	2007	Publication	Cumulative injuries
Guidelines on purchasing bags with potential for reduction of ergonomic risk factors - NIOSH Information Circular	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Reducing Injuries Due to Railcar Loading and Maintenance Activities

Background

A large proportion of mined material is transported via rail. Unfortunately, loading, unloading, maintenance, and other railyard activities can be extremely physically demanding and associated with a high incidence of low back disorders. Workers frequently have to adopt awkward postures when working on the tops of railcars (opening hatches) or when working underneath (opening or cleaning dump points). Many tasks demand the use of a great deal of force, including opening gates with a steel bar, opening steel hatches on covered hopper cars, throwing switches, and setting brakes.



Railworker tending a car dump point

Many challenges are present in trying to improve methods of loading and unloading railcars, particularly since many railcars are leased and not owned (making modifications difficult or impossible) and the railcars tend to be of highly variable design. However, despite these challenges considerable opportunities exist to improve efficiency and reduce musculoskeletal risk through the application of ergonomics principles. As part of a cooperative research effort with the Industrial Minerals Association of North America, NIOSH researchers are currently analyzing tasks associated with railcar loading, unloading, and maintenance activities so that interventions can be developed and implemented to reduce the risk of low back disorders.

Potential Outcome

Expected interventions will include recommendations for improvements in switch design, methods for opening top and bottom hatches, and design and layout of rail facilities. Results of these interventions and recommendations will be presented to the industry through workshops and industry-directed publications. The impact of this research is likely to be realized by 2008. Given the large number of mining companies that use rail for shipment of their products, this work in improving the design of and workplace practices for rail loading, unloading, and maintenance activities has the potential for far-reaching impacts in the mining industry.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Railcar and rail yard ergonomics issues and the reduction of ergonomic risk factors - NIOSH Information Circular	2007	Publication	Cumulative injuries
Guidelines on railcar ergonomics in the mining industry - NIOSH Information Circular	2007	Publication	Cumulative injuries
Workshop presentation to IMA-NA members on Railcar and Railyard Ergonomics	2006	Workshop, Seminar, or OIB	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

MSD Prevention and Intervention Education Modules

Background

Although generic ergonomics training materials have been commercially produced, none of these materials discuss specific ergonomic issues related to mining. As part of the ergonomics process implementation by Bridger Coal Co., NIOSH developed an ergonomics awareness course that was presented to all Bridger employees. As information about this course became known, requests from the mining industry have led to the course being offered several times at both national and local mining conferences and at other mine sites. The popularity of this course has demonstrated a need in the mining industry for courses that not only help companies identify risk factor exposures, but also to control and reduce exposures to these risk factors.



MSD risk factor awareness training session

Three separate training courses will be developed and placed on the NIOSH mining Web page: "MSD Risk Factor Awareness," "Building Better Jobs", and "Designing for Maintainability." The first course is an introductory course with an emphasis on describing work-related musculoskeletal disorders and identifying risk factors associated with the development of MSD's. The second course provides information on how to improve jobs by reducing exposures to risk factors. The final course promotes the design of equipment and workplaces to permit maintenance activities without exposing workers to risk factors during these activities.

Each course will be developed at two levels, the employee level and the trainer level. The employee-level courses will be formatted as Power Point presentations that include interactive exercises and demonstrations and will be designed to be given as classroom training. The trainer-level course will be formatted so it can be accessible on the Internet and be taken as a stand-alone learning experience. The material covered in the train-the-trainer course will prepare a trainer to present the employee-level course. An instructor's kit will be available for downloading to assist trainers when presenting the employee-level course. Each kit will contain an electronic copy of the Power Point presentation, training evaluations for employees, a narrative manual to accompany the presentation, and background information about ergonomics.

Potential Outcome

The primary benefit of this task will be to reduce MSD incidence rates as the mining industry increases its knowledge about MSD risk factors and ways to improve jobs and so reduce exposures to these risk factors. As alternate methods for delivering the courses become available, more trainers will be qualified to offer the courses to their employees. Information about the courses will be available on the NIOSH mining Website, and courses will continue to be given by NIOSH staff at conferences and workshops throughout many mining sectors. Impact of this research is expected to be felt during 2006-2010.

Outputs

7 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
MSD Risk Factor Awareness Train-the-Trainer NIOSH Module presented to safety and health representatives of US Silica, Berkeley Springs, WV, October 2005	2005	Training	Cumulative injuries
MSD Risk Factor Awareness Training Module at Badger Mining Company (Fairwater and Taylor Mines)	2006	Training	Cumulative injuries
Instructor's manual for the MSD Risk Factor Awareness Train-the-Trainer course (Wiehagen-W, Torma-Krajewski-J, Steiner-L), NIOSH IC	2006	Publication	Cumulative injuries
MSD Risk Factor Awareness Train-the-Trainer Module to safety and health representatives of Vulcan Materials Company	2006	Training	Cumulative injuries
Train-the-Trainer Materials for Building Better Jobs: (1) Concept and implementation; (2) Tool design; (3) Anthropometrics and biomechanics for design; (4) Maintenance; (5) Equipment purchasing and retrofitting; and (6) Control design	2008	Training	Cumulative injuries
Designing for Maintainability : Guidelines for Designers and Maintenance Personnel - NIOSH Information Circular	2007	Publication	Cumulative injuries
Designing for Maintainability : Guidelines for Designers and Maintenance Personnel - web version	2007	Web document	Cumulative injuries

Potential Intermediate Outcome for Traumatic Injuries

Guidelines for Improving Ore Pass Safety

Background

Ore passes are constructed within the rock mass for the purpose of vertical transfer of ore and waste rock from stopes or development headings. Their function is to deliver material to a lower haulage level or to shaft loading pockets for hoisting to the surface. The figure shows a typical mine ore pass with truck loadout and LHD vehicle dump.

The ore pass design research was started at the request of MSHA after several fatalities resulted from workers attempting to free clogged ore pass chutes. A review of MSHA injury and fatality data for the 20-year period between 1975 and 1995 shows that nearly 75% of the injuries were directly or indirectly related to pulling or freeing ore pass chutes, the use of hand tools, falls of broken rock, and structural failures of the chute or gate and ore pass walls. During the period 1991-2000, 83 traumatic injuries specifically caused by pulling or freeing hang-ups in chutes were reported in 18 underground metal/nonmetal mines. In addition to ore pass accidents, about one fatality per year resulted from the collapse of coal bridges that formed over feeders on coal surge piles

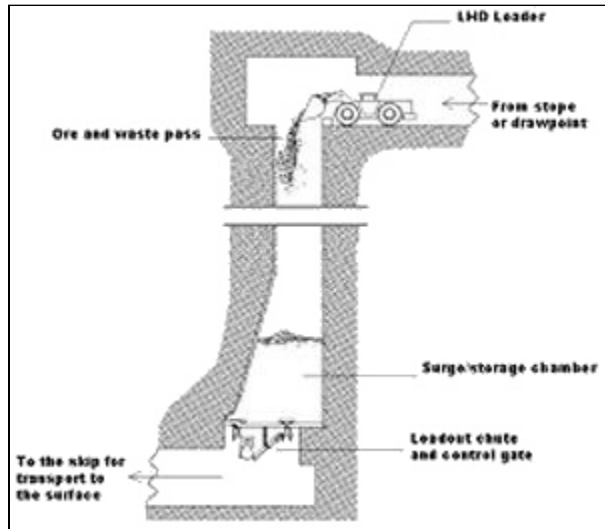


Diagram of a typical ore pass

Particle-flow computer programs have been used in analyzing mine ore and waste passes. Preliminary finite-element analyses determined safety factors of typical ore chute control gates. New algorithms have been developed to characterize ore pass materials and conditions more accurately and specifically, and results of numerical calculations on typical ore pass systems have been validated with experimental observations.

Potential Outcome

Improved ore pass design methods can prevent accidents caused by hang-ups and structural failures. Field tests indicated that particle size and shape and ore pass system stiffness and friction properties must be determined for accurate computer analysis. Highly sophisticated computer modeling routines were adapted as a design tool for mine ore pass designers.

Outputs

11 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Ore Pass Analysis and Design Workshop Co-sponsored by the Western Mining Research Center (WNRC), Golden, CO, Spokane, WA, Dec. 2, 2003	2003	Workshop, Seminar, or OIB	Ground control
Application of Physical Modelling and Particle Flow Analysis to Evaluate Ore-pass Design Beus-MJ; Iverson-S; Stewart-B Inst Min Metall, Trans, Sect A: Min Ind, 1998 Sep 106():A110-A117	1997	Publication	Ground control; Traumatic injuries
Development of a Mine Hoist and Ore Pass Research Facility Beus-MJ; Ruff-TM Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-134, Report of Investigations 9637	1997	Publication	Traumatic injuries
Technology News 458 - Development of a Research Facility to Improve Mine Hoisting and Ore Pass Safety NIOSH Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 458, 1997 May :1-2	1997	Publication	Traumatic injuries
Technology News 470 - Analysis of Hangups and Structural Failure in Underground Mine Ore Passes Stewart-B; Iverson-S; Cullen-E US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 470, 1998 Feb :1-2	1998	Publication	Ground control
Static and Dynamic Loads in Ore and Waste Rock Passes in Underground Mines Beus-M; Iverson-SR; Dreschler-A; Scott-V Rock Mechanics for Industry, Amadei, Kranz, Scott & Smeallie (eds.), 1999 Balkema, Rotterdam, ISBN 90 5809 052 3, :489-495	1999	Publication	Traumatic injuries
Safety Considerations for Transport of Ore and Waste in Underground Ore Passes Stewart-B; Iverson-S; Beus-M Min Eng 1999 Mar; 51(3):53-60	1999	Publication	Traumatic injuries
Technology News 479 - Ore Pass Level and Blockage Locator Device NIOSH US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 479, 2000 Jan :1-2	2000	Publication	Traumatic injuries
Static and Dynamic Loads in a Scaled Ore Pass Scott-VA; Drescher-A; Iverson-S; Beus-M Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000), ed. By J. Girard, M. Leibman, C. Breeds, and T. Doe (Seattle WA, July 31-Aug. 3, 2000). Balkema, 2000; :381-386	2000	Publication	Traumatic injuries
Design of Ore Passes Beus-MJ; Pariseau-WG; Stewart-BM Iverson-SR Ch. 71 in Underground Mining Methods: Engineering Fundamentals and International Case Studies, William Hustrulid and Richard Bullock, eds., Society for Mining, Metallurgy, and Exploration, Littleton, CO, 2001; :627-634	2001	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Investigation of Bulk Solids Engineering Properties and Application of PFC2D to Ore Pass Flow Problems Iverson-SR In: H. Konietzky, ed., Numerical Modeling in Micromechanics via Particle Methods. Proceedings of the 1st International PFC Symposium (Gelsenkirchen Germany, Nov. 6-8, 2002), Balkema, Rotterdam, Netherlands, 2002: :252-258	2002	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Forklift Operating Warning System (FLOWS)

Background

A common danger in the mining, agriculture, and construction industries is that mobile equipment is often unknowingly operated in an unsafe manner. Operator errors are frequently the result of inadequate training, complacency regarding equipment operation, and taking shortcuts. Many times an operator unknowingly operates the equipment beyond its safe operating limits or fails to recognize dangers in the work environment. Unsafe operation can result in injuries and the deaths of both drivers and pedestrian workers; over 100 fatalities and 20,000 lift truck injuries occur yearly in the United States. Seventy percent of these accidents were caused by operator error. In 2000, the leading causes of lift truck fatalities were lift truck overturns (23%), pedestrians and workers struck by lift trucks (39%), and falls from lift trucks (10%). During 1999-2003, over 181 lift truck traumatic injuries were recorded at mining operations where seven or more fatalities had already occurred.



Instrumented lift truck with operator warning system

NIOSH, in collaboration with the North American Coal Company (NACCO), the manufacturer of Yale and Hyster lift trucks, is investigating ways to reduce the high number of injuries and deaths related to dangerous lift truck operating practices. A prototype forklift operating warning system (FLOWS) was developed by NIOSH researchers. This system continuously monitors the critical operating parameters of a lift truck to alert the operator when the vehicle is being operated unsafely. When a critical operating parameter is exceeded, a digital voice warning message is activated that can be heard by both the lift truck operator and any nearby workers. The warning can, for example, alert the operator when he or she is traveling or cornering too fast, nearing pedestrian workers or obstacles, lifting too heavy of a load, and approaching the edge of a loading dock. The sensor-based monitoring system can also be used a tool to improve lift truck operator training, evaluate training programs, and identify areas in need of additional training.

Potential Outcome

The expected impact of this research will be to reduce the 20,000 yearly lift truck accidents in the United States by 20% by 2010.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
High-Tech System to Reduce Forklift Injuries Owens-JK eNews, Volume 2, Number 2, June 2004, http://www.cdc.gov/niosh/enews/enewsV2N2.html#s	2004	Web document	Traumatic injuries
Development of first generation forklift operating warning system (FLOWS), Employee Invention Report (EIR)	2006	Patent	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

High-Voltage Continuous Mining Machines

Background

The demand for larger, more-powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Higher-voltage equipment can supply more power without requiring larger, heavier trailing cables. Special design, use, and maintenance precautions are needed to ensure an equivalent level of safety when high-voltage systems are used in permissible areas. Since 1997, which was before each continuous mining machine operating above 1000-V ac could be put into use, MSHA required a Petition for Modification, and each individual machine was then scrutinized prior to approval.



Typical continuous miner

NIOSH research indicated that higher voltages were indeed feasible with appropriate precautions. Several NIOSH research reports provided technical information used by MSHA to help formulate new regulations that would allow the use of high-voltage longwall machines in coal mines (Final Rule, 30 CFR Parts 18 and 75, "Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines" on March 11, 2002. Published in *Federal Register*, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005). These reports also provided technical information critical to the development of the proposed high-voltage continuous miner rule. Such information included enclosure pressures developed during electrical arcing up to 15 kV in methane-air atmospheres, as well as recommendations for high-voltage electrical creepage and clearance distances, design criteria for explosion-proof enclosures, and permissibility hazard reduction.

Potential Outcome

The proposed rule "High-Voltage Continuous Mining Machines," RIN 1219-AB34, published by MSHA in the *Federal Register* of July 16, 2004 (Vol. 69, No. 136, Proposed Rules, pp. 42811-42840), is anticipated to become law by 2010. The new rule will eliminate the need for each new high-voltage continuous mining machine to undergo the Petition for Modification process. The proposed rule draws on the results of NIOSH research to allow the safe use of explosion-proof continuous miners. The ability to accept high-voltage, continuous-mining-type machines removes a significant barrier to safer, more efficient, and economic coal mining in the United States.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Development of High-Voltage Permissible Loadcenter Berry-DR; Gillenwater-B U.S. Bureau of Mines contract no. H0308093. NTIS No. PB 86-215803	1986	Publication	Traumatic injuries
Mine Electrical Systems Evaluation: Explosion-Proofing of Mine Containers Stefanko-R; Morley-LA University Park, PA: The Pennsylvania State University, College of Earth and Mineral Sciences. U.S. Bureau of Mines Contract Report No. G0-133077, OFR 76(2)-75, NTIS Number: PB/245-928/As, 76 pp	1974	Publication	Traumatic injuries
A Study of Explosion-Proof Enclosures Cox-PA; Burnside-OH; Esparza-ED; Lin-FD; White-RE San Antonio, TX: Southwest Research Institute. USBM contract No. H0-377052. OFR 96-83, NTIS No. PB 83-205450; :426 pp	1982	Publication	Traumatic injuries
A Design Guide for Explosion-Proof Electrical Enclosures - Part 3: Final Technical Report Cox-PA; Schick-WR Southwest Research Institute, USBM Contract Report No. H0-387009, OFR 47c-86, NTIS: PB 86-209525; :353pp	1985	Publication	Traumatic injuries
Mine Power Systems Morely-LA Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9258. NTIS No. PB 91-241729	1990	Publication	Traumatic injuries
Final rule for High-Voltage Continuous Mining Machines	2010	Standards	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Power Line Proximity Warning Alarms

Background

During the 1990's, approximately 20% of all electrocutions in the mining industry resulted from high-reaching mobile equipment, such as cranes, dump trucks, and drill rigs, coming in contact with overhead power lines. In these accidents, 56% of the injured miners were unaware of the shock hazard and contacted both the equipment and ground simultaneously after a power line contact had occurred. An overhead power line contact alarm was developed to supplement existing proximity warning systems. While not designed to prevent all related injuries, a contact alarm can warn workers when a piece of mobile equipment becomes energized by a power line. Two manufacturers plan to supplement their proximity warning alarm systems with contact alarm technology.



A mobile crane working near power lines

Proximity warning systems, advertised as having the capability of alerting operators when they approach too close to a power line, have been commercially available for 30 years. Such systems have not found widespread acceptance due to perceived performance deficiencies and, in part, to a lack of regulatory requirements. The only known comprehensive study of power line proximity warning systems was published by the U.S. Bureau of Mines in 1982. It documented some serious performance limitations. Proximity warning system manufacturers claim to have substantially improved product performance since then. Recent OSHA efforts are underway to improve the 29CFR Crane and Derrick Standard. The proposed language allows the use of proximity warning alarm systems as a means of maintaining OSHA's (and MSHA's) required clearance distances from power lines, provided such systems are approved by a nationally recognized testing laboratory. To allow approval by a third-party testing laboratory, objective performance data must exist from which to develop a standard for use by such laboratories. NIOSH-sponsored work will provide technical data for such a national standard.

Potential Outcome

An American National Standards Institute (ANSI) standard that sets minimum performance and operational criteria for power line proximity alarms is anticipated by 2010. Building on past and current NIOSH power line proximity research, the standard will allow the use of power line proximity warning alarms to protect workers against accidental contact between power lines and high-reaching mobile equipment. The technology can also be applied to reduce power-line-related electrical injuries in the construction industry. Based on an estimated worldwide market of 45,000 proximity warning systems, the overall potential impact on the reduction of power line contact accidents is high.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Alarm System for Detecting Hazards Due to Power Transmission Lines Sacks-HK; Yenchek-MR; Homce-GT; Cawley-JC U.S Patent #6,600,426 (granted July 29, 2003)	2003	Patent	Traumatic injuries
Heavy Equipment Near Overhead Power Lines? New Safety Research May Save Your Life: New Safety Research May Save Your Life Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR Engineering and Mining Journal, (203)4, 2002 Apr :36-39	2002	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers An invited, 90-minute workshop held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004	2004	Workshop, Seminar, or OIB	Traumatic injuries
Electrical Safety for Water Well Drillers NIOSH An invited, 90-minute workshop held twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005	2005	Workshop, Seminar, or OIB	Traumatic injuries
Development of an Overhead Power Line Contact Alarm for Mobile Equipment Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR International Journal of Heavy Vehicle Systems, (12)4, 2005 Apr; :87-103	2005	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers Homce-GT; Cawley-JC; Yenchek-MR Water Well Journal, 59(8); :12,14	2005	Publication	Traumatic injuries
An American National Standards Institute standard that sets minimum performance and operational criteria for power line proximity alarms	2010	Standards	Traumatic injuries
Power line proximity warning alarm test results. IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Design and performance criteria for power line proximity and contact alarm systems. IEEE Trans. on Ind. App.	2008	Publication	Traumatic injuries
Trends in overhead power line electrocution accidents statistics - IEEE Trans. on Ind. App	2009	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Electrical Arc Burns

Background

Between 1990 and 2001, 2,146 traumatic electrical injuries occurred in the mining industry, of which 846 (39%) were burns resulting from electrical arcing. Fifty-five percent of these injuries occurred in bituminous coal, 21% in stone, 10% in sand and gravel, 9% in metal, and 5% in nonmetal mining. No specific guidelines yet exist with which to combat electric arc burn injuries in mining.



Simulated electrical arcing accident

A significant amount of industrial safety research has focused on protecting workers from electrical arcing hazards. The result has been the National Fire Protection Association's (NFPA) national standard 70E-2004, "Standard for Electrical Safety in the Workplace." The scope of NFPA 70E explicitly excludes underground mining. A true need exists to identify the relevant parts of NFPA 70E that can be applied to mining to reduce serious burn injuries.

Potential Outcome

NIOSH research is bringing relevant aspects of NFPA 70E into the mining workplace to afford miners better protection from electrical arcing injuries. This work will use computer simulations to quantify the short-circuit energy available in representative mine electrical systems. Recommendations for the use of arc-rated electrical personal protective equipment (PPE) in mining situations analogous to its use in other industries are being formulated. Advancements in PPE technology have the potential to mitigate the number and severity of arc burn injuries. Training to raise miners' awareness of electric arc burn hazards will be developed. Hazardous tasks commonly encountered by mine electricians are being identified. Task-appropriate, arc-rated fire-retardant clothing, electrical tools, meters, and work practices will be recommended. The anticipated industry impact is expected to be a substantial reduction in the number of arc burn injuries.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Protection from arcing injury in the coal industry - IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Protection from arcing injury in the aggregates industry - SME Journal (peer-reviewed)	2008	Publication	Traumatic injuries
An arc burn training video	2007	Video	Traumatic injuries
Arc burn safety for use in MSHA-required refresher training - NIOSH Information Circular	2007	Publication	Traumatic injuries
Electrical arcing-fault safety measures for mining. IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Selection and use of electrical meters in mining - Min. Engr.	2008	Publication	Traumatic injuries
Tools for safer mine electrical maintenance - Min. Engr.	2008	Publication	Traumatic injuries
Safer mine electrical maintenance - NIOSH Information Circular	2010	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Roof Bolter Health and Safety Guidelines

Background

Hazards arise from work environments and improperly designed workstations, equipment, or work methods. Mine work hazards include machine and human-body appendage collisions and operator errors. Tasks related to boom arm movement have a high degree of hazardous acts, and no data exist on safe speeds for booms operating close to workers in a confined work environment such as is found in underground mines. Incident investigation reports do not usually contain enough information to aid in studying this problem. Laboratory and field experiments with human subjects are not feasible because of safety and ethical issues.



Roof bolting in underground coal

Work-related musculoskeletal disorders (MSD) include awkward postures, repetitive and forceful motions, and excessive jarring and jolting. MSHA injury/incident data from 1993 to 2004 showed a total of 139,222 nonfatal lost time injuries. Repetitive MSD injuries composed 46% of the reported incidents and machinery and powered haulage composed 24%. Research is being conducted to assess and reduce the presence of underground mine work hazards to which the work environment, equipment, and performance of work contribute significantly to roof bolter operations. The fundamental issues being addressed are-What boom appendage speed(s) maximize the operators' chances of escaping injuries while still allowing the operators to perform bolting functions effectively? What equipment design modifications are needed? What job-task-procedure changes are needed to reduce the risk of low back pain unique to the postural and lifting circumstances of roof bolters?

Potential Outcome

This research will suggest changes to roof bolting equipment that would have a direct impact on how the bolting task is performed. Guidelines and control interventions relating to boom speed ranges and procedural modifications of work postures to reduce injuries in the back and other parts of the body are expected. For example, in typical bolting activities, a tray is provided on which to stack material handled during the bolting operation. A guideline that suggests different locations for the materials tray has the potential to reduce low back stress by limiting bending, twisting, and lifting motions. Another example addresses the current situation in which operators can operate a boom arm's speed and direction with one hand. A control intervention, such as redesigning the controls to require the operator to use two hands, has the potential to reduce injuries by keeping the body and hands clear of a moving boom arm. Most impacts resulting from modifications to roof bolting equipment are expected to take place by 2008.

Outputs

11 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Simulation Approach Analyzing Random Motion Events Between a Machine and its Operator Ambrose-DH In: Proceedings of the Digital Human Modeling for Design and Engineering Conference and Exposition, Dearborn, Michigan, June 6-8, 2000. Paper No. 2000-01-2160. Warrendale, PA: SAE International, 2000 Jun; :1-11	2000	Publication	Traumatic injuries
Machine Injury Prediction by Simulation Using Human Models Ambrose-DH; Bartels-JR; Kwitowski-AJ; Helinski-RF; Gallagher-S Warrendale, PA: Society of Automotive Engineers, Inc., technical paper 2003-01-2190, 2003; :1-11	2003	Publication	Traumatic injuries
Mining Roof Bolting Machine Safety: A Study of the Drill Boom Vertical Velocity Ambrose-DH; Bartels-JR; Kwitowski-AJ; Helinski-RJ; Gallagher-S; McWilliams-LJ; Battenhouse-TR Jr Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 2005-128, Information Circular 9477, 2005	2005	Publication	Traumatic injuries
Random Motion Capture Model for Studying Events Between a Machine and its Operator Ambrose-DH Proceedings of the Advanced Simulation Technologies Conference. ASTC 2001, July 15-19, 2001, Orlando, Florida. San Diego, CA: Society for Computer Simulation International 2001 Jan; :127-134	2001	Publication	Traumatic injuries
Technology News 480 - Controlled Start for Drill Motors on Roof Bolting Machines DuCarme-JP US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 480, 2000 Feb :1-4	2000	Publication	Traumatic injuries
Verification and Validation of Roof Bolter Simulation Models for Studying Events Between a Machine and its Operator Bartels-JR; Ambrose-DH; Wang-RC Society of Automotive Engineers, Inc., technical paper 2001-01-2088, 2001 Jan; :1-14	2001	Publication	Traumatic injuries
Verification of a Roof Bolter Simulation Model Bartels-JR; Kwitowski-AJ; Ambrose-DH Warrendale, PA: Society of Automotive Engineers, Inc., Technical Paper 2003-01-2217, 2003; :1-7	2003	Publication	Traumatic injuries
Computer Simulations Help Determine Safe Vertical Boom Speeds for Roof Bolting in Underground Coal Mines Ambrose-DH; Bartels-JR; Kwitowski-AJ; Gallagher-S; Battenhouse-TR Safety Res 2005 Oct-Dec; 36(4):387-397	2005	Publication	Traumatic injuries
Comparing Estimated Low Back Loads from Control Interventions for Underground Mine Roof Bolter Operators Ambrose-DH; Cole-GP KOMAG, KOMTECH Conference, Nov. 14-17, 2005, Zakopane, Poland, 10 pp.	2005	Publication	Traumatic injuries
Survival analytic approach to evaluating struck-by accidents using a virtual human model - Journal of Human Factors	2006	Publication	Traumatic injuries
Roof bolter operator low back stress analysis - Journal of Safety Research	2006	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Reducing Blast Area Security and Flyrock - Related Injuries and Fatalities in Mining

Background

Flyrock injuries and fatalities can result when a worker is struck by rock thrown much further than expected. An indirect cause of flyrock injuries and fatalities is a lack of blast area security prior to a blast. Such incidents result when a worker who was supposed to have left the area of a blast remains within the area and is injured by flyrock. Between 1994 and 2003, flyrock and a lack of blast area security were responsible for 12.8% of the fatalities and 41.6% of the injuries related to blasting.

Miners must be made aware of the importance of blast area security and the hazards of flyrock, as well ways to protect personnel. Training materials to raise blasters' awareness of flyrock hazards and the importance of good blast area security have been developed and will be distributed during FY05.



Flyrock damage to a haul truck

Potential Outcome

As miners are alerted to the hazards of flyrock and poor blast area security, the frequency of this type of accident will decrease. Since flyrock represents the majority of blasting-related injuries and fatalities, the training materials being developed are expected to result in a significant reduction in accidents.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Blasting Safety - Revisiting Site Security Bajpayee-TS; Verakis-HC; Lobb-TE Proc 31st Ann Conf Explos Blasting Tech, Orlando, FL, February 6-9, 2005, 2005 Feb 6; 2:1-13	2005	Publication	Traumatic injuries
An Analysis and Prevention of Flyrock Accidents in Surface Blasting Operations Bajpayee-TS; Verakis-HC; Lobb-TE Proc 30th Ann Conf Explos Blasting Tech, New Orleans, LA, February 1-4, 2004, 2004 Feb; :1-10	2004	Publication	Traumatic injuries
A Summary of Fatal Accidents Due to Flyrock and Lack of Blast Area Security in Surface Mining, 1989 to 1999 Bajpayee-TS; Rehak-TR; Mowrey-GL; Ingram-DK Proc 28th Ann Conf Explos Blasting Tech, ISEE, Las Vegas, Nevada, February 10-13, 2002, 2002 Feb 2:105-118	2002	Publication	Traumatic injuries
Flyrock Issues in Blasting Rehak-TR; Bajpayee-TS; Mowrey-GL; Ingram-DK Proc 27th Ann Conf Explos Blasting Tech, ISEE, Cleveland, Ohio, 2001 Feb, 1:165-175	2001	Publication	Traumatic injuries
Flyrock brochures and video. NIOSH Toolbox Training Materials	2006	Publication	Ground control
Reinforcing the Importance of Maintaining Good Blast Area Security	2006	Video	Ground control

Potential Intermediate Outcome for Traumatic Injuries

Remotely-Controlled Bulldozer on Coal Stockpiles

Background

Approximately 500 bulldozers in the U.S are used to facilitate drawdown at the top of coal stockpiles. Environmental conditions, coal compaction, and other factors can result in voids in stockpiles which can entrap these machines. Since 1980, there have been 19 fatalities at coal stockpiles, the majority being bulldozer operators. Efforts by MSHA and others have led to the development of improved cab designs, high strength windows, and communications which have proven to save operator lives during dozer cover-ups.



Voids in coal stockpiles can entrap bulldozer operators

Providing remote control of the dozer has the potential to totally eliminate the danger to the operator by removing him/her from the machine. Previous attempts in the U.S. to remotely control the dozer were never fully implemented due to a variety of issues. One drawback was that the operator, when removed from the dozer, lost the feel of the machine. This resulted in significant inefficiencies during remote operation compared with on-board control.

Addressing this, NIOSH is engaged in research aimed at mimicking the feel of the machine by adding visual, audio, and vibratory feedback. The approach is to provide the remote operator with sufficient sensory cues so that he/she thinks they are actually operating the dozer on-board. The research project is a collaborative effort with a dozer manufacturer, Caterpillar, and a coal operator, ConsolEnergy. Caterpillar has provided the bulldozer with remote-controls and ConsolEnergy has provided access to their Eighty-Four stockpile. The hypothesis to be tested is that a simulated environment with visual, audio and motion feedback will enhance acceptance of remote control operation of dozers on coal stockpiles.

Potential Outcome

Upon project conclusion, recommendations will be formulated that can be used as guidance for stockpile operators contemplating conversion to remote-control. It is envisioned that the prototype hardware developed by NIOSH will be adapted and sold commercially by bulldozer manufacturers. A successful demonstration could ultimately lead MSHA to recommend remote control of dozers on stockpiles and in the long term, to an increased adoption of this method. This would result in a reduction of incidents and fatalities from dozer cover-ups by removing the dozer operator from the stockpile.

Outputs

1 Planned or completed output

Title	Year	Output Type	Strategic Goal
Recommendations for conversion of bulldozers to remote control - peer reviewed publication, SME Transactions	2007	Publication	Traumatic injuries

Potential Intermediate Outcome for Mine Disasters

Advanced Methane Control in Underground Coal Mines

Background

The mining industry's use of advanced mining technologies has resulted in an increase in methane emissions and the associated risk of explosions or fire. The inability to forecast the potential for hazardous emissions and accumulations of methane or frictional ignitions has led to injuries and deaths among coal miners in underground coal mine explosions. Recent major explosions have occurred in Utah (2 fatalities) in 2000, in Alabama (13 fatalities) in 2001, and in West Virginia (3 fatalities) in 2003.



Methane ignition in the laboratory

Rates of methane emission are unpredictable as a result of changing geologic conditions, in situ gas content, and constantly evolving mining practices, methods, and equipment. In addition, the interaction among these variables is not well known. Methane reservoir simulation software will be used to design and evaluate methane control technologies and strategies for longwall gobs. This software will be combined with commercially available mine ventilation modeling software to help predict methane emissions.

Frictional ignitions of methane and other gases are still relatively common in U.S. coal mines. Numbers have averaged about 60 per year from 1995 to 2004. Coal-measure rocks from both ignition-prone and non-ignition-prone basins will be used to create an index of incendivity that will be forwarded to industry.

Potential Outcome

In 2007, a systematic set of best practices for methane control, as well as premining and active mining evaluation techniques, will be made available to mine operators. Mine engineers will be able to use these techniques in combination with the methane reservoir model to optimize mine design and methane control technology. This will enable a mine operator to better predict methane emissions throughout a mine and design appropriate methane control measures to reduce the risk of methane explosions.

By 2007, the NIOSH-developed modified direct-method apparatus will become commercially available, which will allow mine operators to obtain reliable data on gas content. This will improve the accuracy of the methane reservoir model and further reduce the potential for methane gas explosions.

A qualitative index of incendivity will also become available in 2007. It will provide the industry and regulatory personnel with guidance on the character and likelihood of frictional ignition events and is expected to reduce the number of events leading to mine fires and explosions.

Outputs

9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Remote Gob Gas Venthole Monitoring and Cellular Telephone-Based Real-Time Data Transmission System Garcia-F; Diamond-WP; Marshall-JK In: De Souza E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; :324-329	2002	Publication	Mine disasters
Application of Numerical Models to Investigate Permeability Changes and Gas Emissions Around Longwall Mining Panels Esterhuizen-G; Karacan-CO Proceedings of the 40th US Rock Mechanics Symposium (Anchorage, Alaska), CD-ROM, paper 05-744; :13 pp	2005	Publication	Mine disasters
Numerical Analysis of the Impact of Longwall Panel Width on Methane Emissions and Performance of Gob Gas Ventholes Karacan-CO; Diamond-WP; Esterhuizen-GS; Schatzel-SJ In: Proceedings of the International Coalbed Methane Symposium (Tuscaloosa, AL; May 18-19, 2005). University of Alabama, 2005; :28 pp	2005	Publication	Mine disasters
Occurrence of Frictional ignitions in US underground coal mines, NIOSH RI	2006	Publication	Mine disasters
Kissell, F (ed.) - Methane Control Handbook - DPRB researchers prepared three chapters for this handbook: Explosion Hazards of Coal Dust in the Presence of Methane; Geologic Features and their Influence on Mine Gas Emissions; Forecasting Gas Content, Gas Emissions, and Gas Production from Coalbeds, NIOSH numbered publication	2006	Publication	Mine disasters
The influence of Geologic Factors on in situ Methane Contents and Gas Emissions - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Numerical Modeling of Gas Flows in the Longwall Mining Environment for Methane Drainage and Ventilation Planning - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Reservoir Simulation-based Modeling for Characterizing Longwall Methane Emissions and Gob Gas Venthole Production - International Journal of Coal Geology, peer reviewed	2006	Publication	Mine disasters
A Comprehensive Mine-Wide Gas Flow and Emissions Model - NIOSH RI	2009	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Reducing Fire Hazards in the Metal-Nonmetal Mining Industry

Background

Between 1990 and 2001, 519 fires broke out in the metal and nonmetal segment of the mining industry, resulting in 308 injuries and 5 fatalities. These fires involved a diverse range of flammable materials, equipment, and ignition sources. Although much progress has been made in preventing and controlling fires in the U.S. mining industry, fires within the metal-nonmetal sector still occur at an average rate of about 40 per year. Every fire has the potential to cause significant numbers of injuries and loss of life. The metal-nonmetal mining industry lacks requirements for mandatory fire detection systems or devices

that could warn miners of fire. Research on the causes of fires and the resultant fire hazards is being conducted as a basis for developing strategies, techniques, and products for detection, control, and prevention of fires. Fire safety and fire emergency preparedness training is being developed to address the unique problems of the metal-nonmetal mining industry.



Full-scale test of noise abatement material in a cab

Potential Outcome

In 2006, this project will develop simple, easily deployed, low-cost smoke sensors that could result in earlier fire detection and reduce worker exposure to fire hazards, smoke, and airborne contaminants. Strategies and guidelines for deploying these sensors will also be developed.

By 2007, combustible materials used in metal-nonmetal mines that should be subject to more stringent fire resistance ratings will be identified. Tests and guidelines for use of these materials will be developed. This will impact roughly 80% to 90% of all fires and injuries due to fire within the metal-nonmetal mining industry and will result in reductions in the number of fires and in injuries and fatalities due to fire.

Fire safety training programs and workshops will be developed and conducted from 2005 through 2007 using materials already developed for the coal mining industry as a guide. This will create and increase worker awareness about the hazards of fire and appropriate techniques for response.

A fire preparedness and response checklist for underground metal-nonmetal mines has been developed and is currently being field tested. The list will provide improved strategies and capabilities to prevent and respond to fire emergencies at underground metal-nonmetal mines. The Mine Safety and Health Administration is expected to adopt portions of the checklist for its training materials and for conducting mine fire prevention audits.

Outputs

7 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Flammability of Noise Abatement Materials Used in Cabs of Mobile Mining Equipment Litton-CD; Mura-KE; Thomas-RA; Verakis-HC Proc: Fire & Materials 2003. London: Interscience Communications, 2003 Feb; :297-306	2003	Publication	Mine disasters
Fire Safety in Metal and Nonmetal Mines Workshop Smith-AC Presented at the 10th Annual Safety Seminar for Underground Stone Mines, Dec. 6-7, 2005, Louisville, KY - 58 attendees.	2005	Workshop, Seminar, or OIB	Mine disasters
Fire detection and suppression systems for cabs of large mining equipment - peer reviewed publication, Fire Safety Journal	2006	Publication	Mine disasters
Mine Fire Preparedness and Response Checklist for Underground Metal and Non-Metal Mines - NIOSH IC	2006	Publication	Mine disasters
Fire safety training manual for M/NM mines - NIOSH RI	2007	Publication	Mine disasters
Fire detector evaluation for use in M/NM mines - peer-reviewed journal publication	2007	Publication	Mine disasters
Recommendations and guidelines for selection and use of flammable materials in the M/NM mining industry, NIOSH RI	2007	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Managing Mine Fires

Background

Mine fires continue to be a major hazard in the coal mining industry. Between 1990 and 1999, 152 fires - 87 underground and 65 on the surface - were reported at underground coal mines. These fires resulted in one death and 47 injuries. During the same period, 51 underground fires (nine injuries) were reported in noncoal mines. Although the number of fires and injuries is relatively low, fires that break out in confined spaces have potentially catastrophic consequences.



Smoke reversal from a mine fire experiment

The dynamics of a mine fire - its initiation and growth and its interaction with ventilation, smoke movement, and the effectiveness of fire control methods - are not well understood.

Smoke reversal in a mine entry can pose hazardous consequences for mine evacuation and miner rescue. Inhalation of toxic fire-generated combustion products can be injurious or fatal to miners. The low visibility associated with smoke impedes safe miner escape and rescue. Smoke reversal in a mine entry is complicated by connections (open crosscuts and leakage paths) between the entry and other entries. The smoke layer that accumulates near the roof can migrate into parallel airways, depending on air velocity and the amount of leakage.

An important aspect of controlling a mine fire is to understand how rapidly a fire might spread. Using computational methods, it is possible to model fire spread in a mine entry by paying particular attention to entry dimensions, ventilation air velocity, fuel combustion properties, and char formation processes. This information can be used to develop ventilation control measures to retard or prevent fire spread.

Potential Outcome

By 2008, this research will result in a mine fire simulator that, in response to fire sensor data entered in real time, can determine appropriate smoke management methods and recommend safe escape routes for miners. Using the mine fire simulator in combination with commercially available atmospheric mine monitoring systems will enable mine operators to better plan and execute mine rescue and recovery activities, enhancing safety for escaping miners and mine rescue workers.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
The Critical Ventilation Velocity in Tunnel Fires - A Computer Simulation Hwang-CC; Edwards-JC Fire Safety Journal, 2005 Apr; 40(3):213-244	2005	Publication	Mine disasters
CFD Modeling of Fire Spread Along Combustibles in a Mine Entry -Transactions, Society for Mining, Metallurgy and Exploration, Denver, peer reviewed	2006	Publication	Mine disasters
Fire Generated Smoke Reversal Through Crosscuts From Return to Intake---Experimental and Computational Study, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
CO Dispersion From a Coal Mine Fire in a Mine Entry, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
A mathematical model to determine the effect of ventilation on fire spread in underground coal mines, peer reviewed publication, Fire Safety Journal	2007	Publication	Mine disasters
A real-time mine fire simulator for smoke management in underground mines, NIOSH RI	2008	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Reducing Fire Hazards in Underground Coal Mines

Background

Analyses of fires in the U.S. coal mining industry for the period 1990-2002 indicated that 110 of the 560 reported fires (both underground and surface) were the result of either a flame cutting or a welding operation. These fires resulted in 70 injuries and 2 fatalities. In a 2003 mine accident, a shaft explosion in West Virginia caused by flame cutting resulted in three fatalities and three injuries. The data also show that 17% of the reported underground mine fires were caused by spontaneous combustion. Three of these fires resulted in subsequent methane explosions.



Fire at an underground coal mine in Colorado

The root causes of fires and injuries caused by flame cutting or welding operations will be investigated. New and improved methodologies and technologies are being developed to prevent such fires. Promising direct interventions to prevent flame cutting and welding fires are being evaluated in field tests at underground coal mines. Recent spontaneous combustion occurrences in U.S. underground coal mines are being studied to determine the causative factors and the role of ventilation. These results are being used to develop computational fluid dynamic models to evaluate ventilation schemes to control spontaneous combustion, and to describe ventilation pathways through the immediate gob and the effect of methane control systems on these pathways.

Potential Outcome

Recommendations for changes to flame cutting and welding standards and regulations will be made during 2007. This will reduce the number of mine fires caused by cutting and welding operations. These recommendations will be easily applicable to the metal/nonmetal sector of the mining industry as well.

The project will also identify the best technologies and practices in mine ventilation and spontaneous combustion control to reduce spontaneous combustion, particularly in underground mines that have appreciable levels of methane. By 2009, this work will result in a better understanding and implementation of ventilation schemes as a dual process: control of both methane and spontaneous combustion, leading to a reduction in the number of spontaneous combustion events in underground coal mines.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Numerical modeling of gas flow in U.S. coal mine gob areas with bleeder ventilation systems - 11th U.S./North American Mine Ventilation Symposium	2006	Publication	Mine disasters
Root causes of flame cutting and welding fires in the U. S. coal mining industry - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer-reviewed	2006	Publication	Mine disasters
Workshops and training aids to transfer flame cutting and welding research findings to the coal mining industry [2007-2008]	2008	Workshop, Seminar, or OIB	Mine disasters
Guidelines for flame cutting and welding and fire prevention in underground coal mines - NIOSH RI	2008	Publication	Mine disasters
Gob ventilation computer model to optimize the ventilation schemes to control spontaneous combustion in the U.S. underground coal industry [2009], Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2009	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Communications and Decision Making During Mine Emergencies

Background

It is often during the first crucial minutes of a mine emergency, such as a fire or an explosion, that the activities and decisions determine the outcome. Inaccurate information and less-than-optimum decision-making contributed to the deaths of 13 miners in a coal mine explosion in Alabama in 2001.

Research is being conducted to gain a better understanding of initial responses during the first critical minutes of a mine emergency and to evaluate outcomes with respect to those responses. Focus groups are being conducted across the country with individuals who have been closely involved in emergency situations at mines to obtain their perspectives on the optimum strategies to pursue. Topics covered include initial communications, available information, judgments, and decision-making. The analysis of the data will result in training protocols and interventions to enhance initial response in the first crucial minutes of a mine emergency.



Decision-making during a simulated mine emergency

Potential Outcome

By 2008, this research is expected to result in a better understanding of the appropriate behavior of the mining workforce during emergencies. This will translate into a better understanding of the potential hazards posed by a mine emergency and will enable a quicker response and a more positive outcome to the emergency. Mine operators, government agencies, and emergency responders will be better trained and equipped to plan for emergencies. They will be able to incorporate successful strategies, improve response behaviors, and enhance decision-making skills during mine emergency and rescue operations. This research will thus reduce the exposure of miners to the hazards encountered in these situations. In addition, the sharing of this information on behaviors in the first critical moments of a mine emergency has application to the broader emergency response community.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
The Emergency Communication Triangle Mallett-L; Vaught-C; Brnich-MJ US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-157, 1999 Oct; :1-16	1999	Publication	Mine disasters; Surveillance and training
The First Critical Hours: Before the Mine Rescue Team Arrives, Proceedings, Sixth International Conference on Occupational Stress & Health "Making a Difference in the Workplace"	2006	Publication	Mine disasters
Communications and decision making during the initial phase of a mine emergency, Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters
Videotapes, workbooks and similar training interventions to transfer research findings to the mining industry - NIOSH communications	2007	Training	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Utilization of Engineered Ventilation Systems in Large Opening Mines

Background

Continuing and emerging air quality issues in meta-nonmetal mines deal with the presence of silica dust, diesel particulate matter (DPM), noxious gases (from diesel equipment, cutting and welding, and production blasts), and the lack of visibility due to fog. A study by the Mine Safety and Health Administration (MSHA) in 2003 found that nearly 22% of metal mines and over 16% of stone mines in the United States had air samples that exceeded the DPM regulatory limit of $400 \mu\text{g}/\text{m}^3$ total carbon. Underground stone miners are frequently exposed to respirable crystalline silica dust in addition to DPM. Chronic

overexposure to silica dust can lead to silicosis, a progressive, irreversible condition caused by deposition of silica dust in lung tissues. Analysis of MSHA's compliance dust-sampling data collected from 1993 to 1998 showed that 15% of the dust samples from underground stone mines exceeded the permissible exposure limit (PEL) for silica dust. Certain occupations, namely truck drivers, crusher operators, front-end loader operators, and rotary drill operators, had a higher risk of exposure and, on average, 20% to 25% of the samples exceeded the PEL.

These issues are of particular importance in mines with large openings. However, these contaminants can be effectively reduced by using engineering controls such as cleaner engines and filters and proper ventilation methods. Adequate ventilation in these mines generally requires a combination of large air quantities and effective planning and placement of ventilation control devices, such as auxiliary fans and stoppings.

Potential Outcome

This project will lead to the use of flexible ventilation stoppings and various auxiliary fan types to increase face ventilation efficiencies. Highly efficient mine ventilation layouts will improve the delivery of ventilation airflow to the working face, thereby reducing worker exposure to airborne contaminants. By 2009, a comprehensive toolbox of ventilation guidelines in the form of a ventilation design handbook for large-opening underground mines will be available. These guidelines will lead to a significant increase in the percentage of large-opening mines that use a highly efficient, engineered ventilation system that provides improved air quality to miners.



Propeller fans installed in a large-opening mine

Outputs

9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF In: De Souza E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
A Computer Software Program that Estimates Air Quantity Requirements in Large Opening Stone Mines Robertson-SB; Grau-RH; Dolgos-JG; Mucho-TP In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :363-369	2004	Publication	Mine disasters
Novel Stopping Designs for Large Opening Metal/nonmetal Mines - Aggregate Manager Magazine	2006	Publication	Mine disasters
Working Mine Ventilation Layouts for Large Opening Stone Mines - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Overview of Improved Mine Ventilation Practices in Large Opening Mines - Proceedings, 11th US/North American Ventilation Symposium, State College	2007	Publication	Mine disasters
Designing a Large Opening Mine using Ventilation Considerations - Aggregate Manager Magazine	2007	Publication	Mine disasters
Improving Face Ventilation in Large Opening Mines - Society for Mining, Metallurgy and Exploration Annual meeting, peer reviewed	2009	Publication	Mine disasters
Ventilation Design for Large-Opening Mines - NIOSH IC	2009	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Remote Construction of Seals for Fire Control and Abatement

Background

Since 2000, 18 underground coal mine fires have been reported in the United States. On average, three mine fires have occurred each year, and from 2000 to the present, a maximum of five mine fires have occurred in a 1-year period. It is thought that remotely constructed mine seals could have been used in over 60% of the fires as a safer means to control the fire and reduce hazards to mine emergency responders.



The direct approach to fighting and sealing off a mine fire places miners in proximity to the fire and exposes them to deadly hazards such as toxic combustion gases, heat, and deteriorating mine roof conditions. To reduce this exposure, an indirect approach of sealing and isolating the atmosphere or flooding the fire area is preferred.

Complete closure of a mine void using improved remote sealing technology

Where safe underground access is impossible, fire seals must be constructed remotely. However, remote sealing often fails to close off the mine entry adequately. In this situation, the seals do not provide effective barriers to airflow or cannot be used to impound water. This research will improve the state of the art for construction of reliable and effective mine seals through engineering design and full-scale testing at the Lake Lynn Experimental Mine. A technology transfer program will disseminate research results to the mining industry.

Potential Outcome

By 2007, several remote-sealing alternatives will be available for mine fire emergencies. The successful use of these technologies will lead to efficient mine fire management and will reduce exposure of miners and mine rescue workers to the hazards of firefighting and rescue operations. If miners are trapped or barricaded inside a mine during a fire, remote sealing can provide an effective way to isolate them from the fire zone, improving their chances for survival and rescue.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Technology For Remote Mine Seal Construction Trevits-MA; Urosek-JE 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-185. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-4	2002	Publication	Mine disasters
Demonstration of Remote Mine Seal Construction Gray-TA; Trevits-MA; Crayne-LM; Glogowski-P 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-194. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-8	2004	Publication	Mine disasters
Remotely Installed Mine Seals for Mine Fire Control - Transactions, Society for Mining, Metallurgy and Exploration, Inc. Annual Meeting, St. Louis, peer reviewed	2006	Publication	Mine disasters
Evaluation of Remotely Installed Mine Seals for Fire Control, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Prevention of Catastrophic Coal Dust Explosions in Mines

Background

Although much progress has been made in preventing disasters in mines, explosions still occur, sometimes producing multiple fatalities. There were serious underground coal mine explosions in 2000 in Utah (2 fatalities and 8 injuries), in 2001 in Alabama (13 fatalities and 3 injuries), and in 2003 in West Virginia (3 fatalities and 3 injuries). These events show that the mine explosion problem has not yet been solved.

Underground explosions can be prevented by minimizing methane concentrations through ventilation and methane drainage, by adding sufficient rock dust to stabilize coal dust, and by eliminating ignition sources.



Mapping debris from a partially destroyed stopping

A handheld coal dust explosibility meter (CDEM) is being developed as a more rapid and objective method to verify the rock dust content of coal and rock dust mixtures. Measurements are based on optical reflectivity for rapid in situ determination. Several commercial prototypes have been built, and in-mine evaluations by the Mine Safety and Health Administration (MSHA), the United Mine Workers of America, and various mine operators will continue through 2006.

Explosion effects can be mitigated by (1) the use of passive and active barriers to suppress explosions and (2) the use of high-strength seals to prevent the propagation of gob explosions into working areas of the mine. Research on the causes and mechanisms of gas and dust explosions, as well as on the use of passive and active barriers, will be conducted at the Lake Lynn Experimental Mine as a basis for developing techniques and strategies for explosion prevention, suppression, and mitigation in underground mines and surface facilities.

Potential Outcome

This research will reduce the likelihood of explosions in coal mines by providing the following:

- Recommendations on best practices to prevent and/or mitigate explosions in the mining industry by 2007.
- Improvements in the knowledge base of mining personnel regarding the recognition and prevention of explosions through presentations and videos to the mining industry, including training courses at MSHA's National Mine Health and Safety Academy during 2006-2007.

- Recommendations for improved forensic accident investigation procedures for MSHA through discussions with and briefing reports to MSHA and through joint publications with MSHA (to be completed in 2006).
- The widespread use of the CDEM by the mining industry will improve management of day-to-day rock-dusting operations. This will help the operator quickly identify accumulations of combustible coal dust and reduce the risk of catastrophic coal dust explosions.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Experimental Mine and Laboratory Dust Explosion Research at NIOSH Sapko-MJ; Weiss-ES; Cashdollar-KL; Zlochower-IA J Loss Prev Process Ind 2000 May; 13(3):229-242	2000	Publication	Mine disasters
Coal Dust Inerting and Postexplosion Dust Sampling Research in a 1-M3 Laboratory Chamber and an Experimental Mine Cashdollar-KL; Going-JE In: Proceedings of the 2003 Technical Meeting of the Eastern States Section of the Combustion Institute (The Pennsylvania State University, University Park, PA, October 26-29, 2003). Pittsburgh, PA: The Combustion Institute, 2003; :97-100	2003	Publication	Mine disasters
Weiss ES, Cashdollar KL, Harteis SP, Shemon GJ, Beiter DA, Urosek JE - Explosion Evaluations of Ventilation Stoppings. NIOSH RI	2006	Publication	Mine disasters
Technical evaluation of the coal dust explosibility meter - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2006	Publication	Mine disasters
Explosion Evaluations of Mine Ventilation Stoppings - Proceedings, 11th U.S./North American Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
Training Materials for MSHA and the mining industry on explosion hazard recognition and preventive measures for underground coal mines - NIOSH RI	2006	Publication	Mine disasters
Determination of the Sizes of Coal Dust in Intakes and Returns of Underground Mines - peer reviewed journal publication	2007	Publication	Mine disasters
Post-Explosion Dust Analyses as a Method of Studying Coal Dust Explosions - journal publication	2007	Publication	Mine disasters
Summary of LLEM Explosion Research, 1999 to 2004 - NIOSH RI	2007	Publication	Mine disasters
Explosion Temperatures of Metals and Other Elemental Dusts - Combustion and Flame, peer reviewed	2008	Publication	Mine disasters

Potential Intermediate Outcome for Ground Control

Improved Highwall Stability to Reduce Surface Mine Hazards

Background

Between 1995 and 2004, 44 miners died in slope failure accidents at surface mines in the United States. While less than 1% of reported accidents are associated with slope stability problems, slope failures were responsible for about 13% of surface mine fatalities. Research was conducted to reduce injuries and fatalities associated with slope failures in surface mines by investigating ways to minimize hazards associated with ground movements.



Highwall failure at surface mine

New technologies to improve slope stability information have been one focus of slope stability research. Hyperspectral imaging, interferometric radar, and time-lapse and video monitoring systems were developed and field tested in collaboration with other researchers (e.g., Dr. Louis Denes, Carnegie Mellon Research Institute; Dr. David Long, Brigham Young University). Prototype instruments were used to demonstrate that slope conditions and rock movements can be detected and recorded. Building on these technologies will result in practical commercial instruments to reduce hazards associated with unstable highwalls. One vendor (SiteWatch Systems, Irving, TX) now offers a trailer-mounted, solar-powered video surveillance system to mine operators after working with NIOSH researchers to develop a prototype.

A second focus of research has been to develop computer programs to assess the effectiveness of rock slope designs. Programs designed in collaboration with Dr. Stan Miller, University of Idaho, use fracture data collected by cell or line mapping on the slope to provide a probability as to whether a useful bench of a given width will be retained to catch rocks falling from upper levels.

A third focus has been to find ways to improve practices for working around mine slopes. A slope safety training video (*The Sky Is Falling*) was produced to improve worker awareness of the hazards associated with mine slopes. As industry uses the training materials (more than 600 copies of the video and trainer guides have been disseminated) the occurrence of injuries related to rock falls and slope failures in surface mining will decrease.

Potential Outcome

By 2010, the highwall monitoring technologies, computer programs, and user's guide promoted and developed with this research should improve the safety and reliability of slope design in fractured rocks, especially in conjunction with advances in automated fracture mapping. One immediate impact of the research has been the use of imagery to collect geotechnical data on mine slopes (Dr.

John Kemeny, University of Arizona). In addition, we expect that improved effectiveness of catch benches will result in fewer injuries in mines. Special emphasis will be to continue to work with academia, particularly mining and engineering schools where design and construction of catch benches are taught.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Advances in Remote Sensing Techniques for Monitoring Rock Falls and Slope Failures Girard-JM; Mayerle-RT; McHugh-EL Proc 17th Intl Conference on Ground Control in Mining, 1998 Aug :326-331	1998	Publication	Ground control
A Portable Spectro-Polarimetric Imager: Potential Mine Safety and Geologic Applications Sabine-C; Denes-LJ; Gottlieb-M; Kaminsky-B; Metes-P; Maycrle-RT; Girard-JM Proceedings of the Thirteenth International Conference, Applied Geologic Remote Sensing, Vancouver, British Columbia, Canada, 1-3 March 1999; 1:1190-1194	1999	Publication	Ground control
Current Research on Slope Movement in Mines: Use of Hyperspectral Imagery McHugh-EL; Girard-JM; Denes-LJ; Metes-P; Sabine-C 14th International Conference on Applied Geologic Remote Sensing, 2000 Nov Las Vegas, NV :1-8	2000	Publication	Ground control
Computer Modeling of Catch Benches to Mitigate Rockfall Hazards in Open Pit Mines Miller SM; Girard JM; McHugh E Pacific rocks 2000: Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000), ed. By J Girard, M. Leibman, C. Breeds, and T. Doe (Seattle WA, July 31-August 3, 2000). Balkema, :539-545	2000	Publication	Ground control
Simplified Hyperspectral Imaging for Improved Geologic Mapping of Mine Slopes McHugh-EL; Girard-JM; and Denes-LJ In: Meech JA, Veiga SM, Viegaa MM, LeClair SR, Maguire JF, eds. Proc Third International Conference on Intelligent Processing and Manufacturing of Materials, 2001, (Vancouver, BC, July 29-Aug 2, 2001); CD-ROM (available from author)	2001	Publication	Ground control
Evaluating Techniques for Monitoring Rock Falls and Slope Stability McHugh-E; Girard-J 21st Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :335-343	2002	Publication	Ground control
Video Motion Detection for Real-Time Hazard Warnings in Surface Mines McHugh-E 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-74. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Ground control
Applications of the Point Estimation Method for Stochastic Rock Slope Engineering Miller-S; Whyatt-J; McHugh-E Gulf Rocks 2004: Proceedings, Rock Mechanics Across Borders & Disciplines, 6th North American Rock Mechanics Conference, June 5-10, 2004, Houston, Texas. Report No. ARMA/NARMS 04-517. Alexandria, VA: American Rock Mechanics Association, 2004 Jun; :1-12	2004	Publication	Ground control
Analysis of Bench Crest Performance at the Yellowstone Mine: A Case Study Whyatt-J; McLaughlin-M; Miller-S Proceedings of the 39th Symposium on Engineering Geology and Geotechnical Engineering: Research to Practice, May 18-19, 2004. M. McLaughlin and R. McNeary, eds., Butte, MT: Montana Tech of the University of Montana, 2004 May; :149-163	2004	Publication	Ground control
NIOSH Computer Programs for Bench Crest Failure Analysis in Fractured Rock Whyatt-J; Miller-S; Dwyer-J In: Dessureault SD, Ganguli R, Kecojovic V, Dwyer JG, eds. Application of Computers and Operations Research in the Mineral Industry. Proceedings of the 32nd International Conference (APCOM) (Tucson, AZ, March 30-April 1, 2005). Balkema, 2005; :439-446	2005	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Reducing Injuries by Improving Shotcrete Design Criteria

Background

Falls of ground are one of the leading causes of injuries and fatalities in underground mines. During the 1990's, gold mining expanded significantly in Nevada. Most of the geological formations are in weak rock, and the occurrence of injuries caused by rock falls doubled.

NIOSH collaborated with several underground gold mines in Nevada to evaluate the use of fiber-reinforced shotcrete against the standard application of steel screen and shotcrete. The amount of fibers was varied to determine the amount that would produce optimum support performance. To conduct this work, an Australian round panel testing system was designed, built, and tested. This system gives mines the capability of testing shotcrete in situ to optimize the design and engineering parameters of the support application. The field test confirmed there were statistically significant improvements in ground control when fiber-reinforced shotcrete was used and subsequently improvements in the safety of the underground miners. Several other mines in Nevada have utilized these tests to improve their underground support. The panel tests conducted at the mine showed positive results for initial failure and energy absorption. With this testing program, mine engineers can determine the characteristics of the shotcrete on site.



Portable shotcrete panel tester

Potential Outcome

The application of fiber-reinforced shotcrete as an alternative to shotcrete reinforced with steel screen reduces worker exposure to potential rock falls and to materials-handling injuries by eliminating the time and manual labor involved in placing screen panels during installation. Research results also indicate that fiber is more effective in reinforcing shotcrete and thus improves the performance of primary support. When this research is completed, design criteria will be published to guide selection and application of shotcrete as a means of rock support. As this technology is adopted and applied by the mining industry over the next 5 years, fewer injuries caused by rock falls should result.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Tests of Fibre-Reinforced Shotcrete at the Chief Joseph Mine, Butte, Montana Martin-L; Dunford-J; MacLaughlin-M; Cronoble-R Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-20, 2005; :6 pp	2005	Publication	Ground control
New Methods to Determine Shotcrete Adhesion in Mines - International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
Effects of Fiber Types on Resin Reinforced Shotcrete Panels - International Conference on Ground Control in Mining	2007	Publication	Ground control

Potential Intermediate Outcome for Ground Control

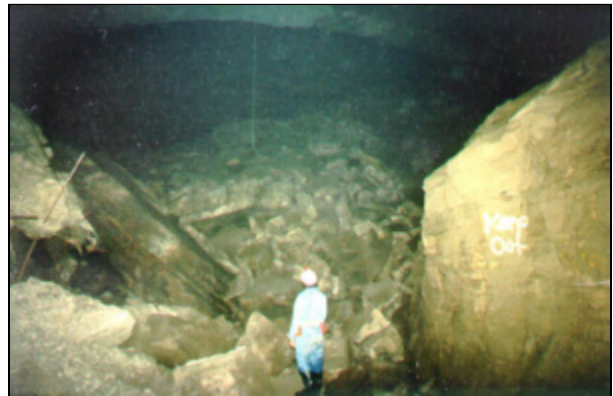
Improved Pillar Design in Metal and Industrial Mineral Mines to Reduce Ground Control Hazards

Background

Room-and-pillar mining is the most widely used underground mining method in the world and, in practice, is utilized in one form or another in most other procedures, particularly during mine development. In the United States, various types of room-and-pillar methods have been used to mine a broad range of mineral commodities, including lead and zinc in Missouri, trona in Wyoming, potash and uranium in New Mexico, and limestone, coal, and salt throughout the country.

Accurate design of pillars left in place to support the roof is critical to maintaining a safe mine. If the dimensions of these remnant support pillars and the room spans between pillars are not designed properly, the long-term stability of underground workings can be compromised, resulting in catastrophic chain pillar failures and dramatic collapses of large areas underground. Stability problems are often exacerbated through attempts to increase resource recovery by reducing the size of support pillars and/or mining high-grade remnant ore pillars, which can create large unsupported roof spans or spans that depend on backfill to carry the overburden load. During the last 10 years, roof falls have been the fifth leading cause of mining accidents, resulting in over 1,500 accidents per year.

Research is being conducted at underground lead mines to gain a better understanding of the conditions that cause roof and support pillar failures and to develop engineering practices that will reduce these ground fall hazards. Data are currently being collected and analyzed from instruments installed in support pillars in a retreat section. Another section has been targeted for additional instrumentation because a wide roof span will be supported with cemented backfill. In conjunction with instrument data, numerical modeling results are being used to analyze the pre- and post-yield stress-versus-strain behavior of pillars to quantify their capability of supporting the mine roof before and after they fail.



Roof failure in a lead mine

Potential Outcome

Collaborative research with the Doe Run Co. in one of the company's seven mines in the Missouri New Lead Belt has addressed concerns regarding the safe extraction of support pillars. By using visual observations, numeric modeling, and instruments to evaluate remnant pillar extraction in a test section of the mine, safety guidelines for maximum roof span, required backfill strength, and instrument placement design were established and published in conference proceedings. The mine staff's goal of no lost-time injuries during pillar extraction was met the first 9 years after guidelines from the test section were implemented.

The future impact from this research will be to use measurements of pillar behavior to develop more precise guidelines for pillar design. This will immediately benefit the seven operating mines in the New Lead Belt, and the methodology can be applied to all pillar mines. This research received the Applied Rock Mechanics award from the American Rock Mechanics Association in 2004.

Outputs

12 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Stability of Backfilled Cross-Panel Entries During Longwall Mining Seymour-B; Tesarik-D; Larson-M; Shoemaker-J Proc 17th International Conference on Ground Control in Mining, 1998 Aug :11-20	1998	Publication	Ground control
Material Properties Affecting the Stability of a 50-Year-Old Rock Dump in an Active Mine Tesarik-DR; McKibbin-RW NIOSH Report of Investigations 9651, 1999 Dec; :1-28	1999	Publication	Ground control
Long-Term Stability of a Backfilled Room-and-Pillar Mine Tesarik-D, Seymour-B, Yanske-T Field Measurements in Geomechanics. Proceedings of the 5th International Symposium on Field Measurements in Geomechanics, Singapore, Dec. 1-3, 1999, C. F. Leung, S. A. Tan, and K. K. Phoon eds., Balkema, 1999 Dec; :431-435	1999	Publication	Ground control
Determination of In Situ Deformation Modulus for Cemented Rockfill Tesarik-DR; Seymour-JB; Jones-FM Technology Roadmap for Rock Mechanics, 10th Congress, International Society for Rock Mechanics (Sandton [Johannesburg], S. Africa, Sept. 8-10, 2003), S. African Institute of Mining and Metallurgy Symp. Series, S33, Vol. 2, 2003 Sep; :1209-1220	2003	Publication	Ground control
Post-Failure Behavior of Two Mine Pillars Confined with Backfill Tesarik-DR; Seymour-JB; Yanske-TR International Journal of Rock Mechanics and Mining Sciences, vol. 40, 2003; :221-232	2003	Publication	Ground control
Temperature Corrections to Earth Pressure Cells Embedded in Backfill Tesarik-DR; Seymour-JB; Williams-TJ; Martin-LA; Jones-FM NIOSH Report of Investigations # 9665, Spokane, WA, December, 2005. 32pp.	2005	Publication	Ground control
Deformation in Undercut Backfill Cap - CIM	2006	Publication	Ground control
Backfill Span Stability Study at the Turquoise Ridge Mine, NV - Proceedings of the U.S. Rock Mechanics Symposium	2006	Publication	Ground control
Long-term Rock and Backfill Monitoring Using Vibrating Wire Instruments - paper in Field Measurements in Geomechanics	2007	Publication	Ground control
Practical Guidelines for Monitoring the Ground Support Behavior of Cemented Backfill - SME Transactions Paper	2007	Publication	Ground control
Support Pillar Behavior During Retreat Mining in a Lead/Zinc Mine - paper at International Backfill Symposium	2008	Publication	Ground control
Monitoring Regional Ground Conditions During Pillar Extraction - paper at U.S. Rock Mechanics Symposium	2009	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Avoiding Inundations: Developing Guidelines for Mining near Bodies of Water

Background

Rock bursts, coal bumps, and other large-scale dynamic failures represent serious ground control problems facing miners in certain industry sectors. These low-probability/high-consequence events often result in severe injuries or death and have the potential to affect an entire underground workforce. When mining near bodies of water, dynamic strata failure also poses potential hazards as a result of changes in rock mass permeability and shaking-induced damage to impoundment structures. An inability to address these problems effectively can result in resource abandonment and/or mine closure and a significant economic impact on entire communities.

Potential Outcome

Research personnel are engaged in joint demonstration and research projects with the mining industry using seismic monitoring tools to advance worker safety through several different avenues. Expected results include:

- Providing quantitative understanding of dynamic failure processes for developing effective hazard mitigation techniques.
- Providing data that can be used to develop empirical ground motion relations for establishing guidelines for safe mining near bodies of water.
- Facilitating adoption of technology and/or guidelines by industry to avoid or mitigate hazards.

By 2010, the results of this research will provide mine operators with the techniques needed to mine safely around bodies of water.



Surface seismometer installation

Outputs

9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Automated-PC-Networked-Based Seismic Monitoring Systems Applied to Mining Hazards Research Swanson-P Seismological Research Letters, 71(1), 2000; :234	2000	Publication	Ground control
Development of an Automated PC-Network-Based Seismic Monitoring System Swanson-P Proceedings of the 5th International Symposium on Rockbursts and Seismicity in Mines (Johannesburg, S. Africa, Sept. 17-19, 2001), G. van Aswegen, R.J. Durrheim, and W.D. Orlepp, eds., S. African Institute of Mining and Metallurgy, Johannesburg, S. Africa, 2001 Dec; :11-17	2001	Publication	Ground control
Feasibility of Using Laser-Based Vibration Measurements to Detect Roof Fall Hazards in Underground Mines Swanson-P In: Proceedings of the Fifth International Conference on Vibration Measurement by Laser Techniques: Advances and Applications. Bellingham, WA: International Society for Optical Engineering (SPIE), Vol. 4827, 2002 :541-552	2002	Publication	Ground control
Seismic Event Data Acquisition and Processing: Distribution and Coordination Across PC-Based Networks Swanson-P; Kenner-B; Krahenbuhl-T In Application of Computers and Operations Research in the Mineral Industry: Proceedings of the 30th International Symposium (APCOM 2002), ed. By S. Bandopadhyay (Feb. 25-27, 2002, Phoenix, AZ). Soc. Of Min. Metall., and Explor., Littleton, CO, 2002 Feb; :637-647	2002	Publication	Ground control
Damage Delineation in Structures Using Laser Vibrometry and Remote Excitation Swanson-P; Rettkowski-J Proc 2004 SEM X Intl Congress and Exposition on Experimental and Applied Mechanics (Costa Mesa, CA, June 7-10, 2004). Bethel, CT: Society for Experimental Mechanics, 2004 Jun; :1-7	2004	Publication	Ground control
Monitoring Longwall Coal Mine Seismicity With a Wireless Strong-Motion Accelerometer Network- Paper in the Proceedings of the U.S. Rock Mechanics Symposium	2006	Publication	Ground control
Relationship Between Ground Motions, Seismic Event Magnitude and Distance at a Western Longwall Coal Mine - peer reviewed paper in the Journal of Geophysical Research	2007	Publication	Ground control
Seismically Determined Longwall Coal Mine Failure Mechanisms - peer reviewed paper in the International Journal of Rock Mechanics and Mining Science	2008	Publication	Ground control
Real-time Seismic Monitoring of a 100-Square Mile Longwall Coal Mining District - Paper in the Proceedings of the International Conference on Ground Control in Mining	2009	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Improved Mine Safety through Optimized Extraction

Background

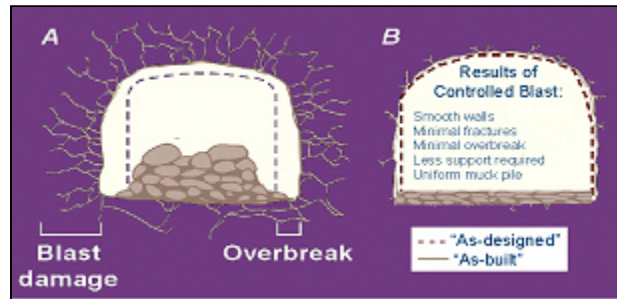
Falls of ground are a significant hazard for miners and a leading cause of fatalities. MSHA data from 1998-2002 indicate that 61 of 141 (43%) of the underground fatalities during that period were caused by fall of ground. Where drill-and-blast techniques are used to excavate rock, poor blasting design or practices can exacerbate support problems, increasing worker exposure to hazards.

Heavily damaged rock surrounding excavations requires more scaling, more support, and hence more rock bolt drilling than less-damaged rock. Substantial damage to the rock mass and poor blasting practices can also contribute to rock falls even after support systems have been put in place and may contribute to additional health and safety hazards involving:

1. Secondary breaking of oversize rock, manually or by drilling and blasting,
2. Undetonated explosives in muck piles, blast hang-ups, or an increase in noxious fumes,
3. Overbreak resulting in irregular opening surfaces that negatively impact ventilation and create uneven roadways, or
4. Ground shocks of sufficient intensity to damage mine equipment and infrastructure.

A number of cases of successful controlled blasting trials at mining operations have been published. However, even though techniques to minimize blasting damage exist, they are not systematically being applied throughout the U.S. mining industry. The goal of the proposed research is to provide the design criteria for optimizing blast designs and to demonstrate that better perimeter control and support system designs for excavations that incorporate advanced fragmentation techniques can significantly decrease the number of accidents associated with ground fall injuries from blast-damaged rock. Major project tasks include:

1. Evaluation of both laboratory and field of blast damage models to validate those that realistically predict the relationship between charge density, explosive energy, distance, rock material properties, rock structure, and rock damage in a spectrum of rock types,
2. Building a database of dynamic rock properties and developing laboratory and field analytical methods to assist industry in predicting the extent of blast damage,
3. Developing a fragmentation/support index that uses geological and geotechnical assessments to estimate rock blastability, rock mass quality, and support requirements,
4. Assessing current industry blasting practices at cooperating mines to quantify results of varying blast designs,
5. Conducting field demonstrations of optimized rock extraction that include improved support application, and



Rock excavated with (A) excessive blasting and (B) controlled blasting

6. Conducting a thorough cost analysis to evaluate and compare costs of industry's current practices to the NIOSH-optimized rock extraction systems.

Results of the research will be communicated to the mining community and the effectiveness of this research in changing blasting practices and reducing injury rates due to ground-control-related accidents will be assessed.

Potential Outcome

This research will develop new, scientifically valid, yet practical methods to provide recommendations on blast design, blast damage assessment, safer scaling, rehabilitation, and ground support installation. The efficiencies gained by integrating the design of the excavation/support process will result in a reduction of fatalities and traumatic injuries when rock is blasted in underground mines. The results of this research will be available to industry by 2010.

Outputs

11 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Near Field Effects Due to Blasting - Paper in the Proceedings of the Symposium on Engineering Geology and Geotechnical Engineering	2006	Publication	Ground control
Sprayable Liner Flexibility Tests on Low RMR Rock Types - Paper in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock	2006	Publication	Ground control
Overview of Current and Emerging Technologies for Performing Blast Damage Assessment in Underground Mines - Paper in the Proceedings of the International Conference on Ground Control in Mining	2006	Publication	Ground control
Theoretical Fundamentals of the New NIOSH Controlled Blasting Software - Paper in International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
A Description of the NIOSH Software for Controlled Blasting in Tunneling - Paper in Journal of Safety Research	2006	Publication	Ground control
A Comparison of Cylindrical Charge Models - Paper in the International Journal for Blasting and Fragmentation	2006	Publication	Ground control
An Economic Evaluation of Perimeter Control Blasting in Drifting - Paper at the annual meeting of Soc. For Mining, Metallurgy, and Exploration	2006	Publication	Ground control
Laboratory Determination of Dynamic Rock Properties - Paper in the International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
A New Procedure for Damage Zone Prediction in Rock - Ph.D. dissertation	2006	Publication	Ground control
Blasting Response in a Weak Rock Mass and Its Effect on Ground Support/Ground Instability - Paper in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock	2007	Publication	Ground control
The NIOSH Initiative for Promoting Safer, More Economic Drifting in Underground Metal/Non-Metal Mines, Proceedings of the International Symposium Fragblast -8, Santiago, Chile, 2006 (abstract accepted)	2006	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Multiple-Seam Mining Design Guidelines

Background

Studies show that 70% of underground coal mines face multiple-seam mining situations where the likelihood of encountering hazardous ground conditions is high. Knowing the location of prior mining, planning engineers may seek to access and mine new reserves above or below old workings. In such situations, two common questions arise:

1. Will workings above or below cause excessive stresses in the proposed workings that could lead to rock falls, pillar bumps, or water inundations?
2. Will subsidence from workings below cause destructive ground control conditions in the upper seam?



Ground control problems created in the seam 170 feet above an extracted longwall panel

Whether an adverse multiple-seam mining situation exists or not depends on numerous factors, including mining geometry, mine design, and geology. Project researchers have collected well over 250 case histories of multiple-seam mining interactions. Case parameters include geometric factors (depth, seam thickness, and interburden thickness), geologic factors (roof rock CMRR, percentage of sandstone in interburden), mining factors (Analysis of Retreat Mining Pillar Stability factor, or ARMPS, panel width, percentage of extraction), and finally a rating that describes the degree of interaction, from "none" to "mining abandoned." Using the boundary-element program LaModel, project researchers are presently examining numerous case histories to quantify the stress and displacement conditions that may lead to adverse multiple-seam mining interactions.

Potential Outcome

Based on statistical analyses of the case history database and numerical models of failure mechanics, design tools will be developed for evaluating and controlling potential multiple-seam mining interactions in 1 year. This design tool will take information about mining geometry, mine design, and geology and evaluate the potential for a multiple-seam mining interaction. In addition, the design tool will forecast the likely magnitude of the interaction. This tool will likely take a form similar to the successful ARMPS program and is tentatively named ARMPS-MSM (for multiple-seam mining).

These design tools will be widely distributed to our stakeholders through classes at the MSHA Academy and open-industry briefings throughout the coal fields. It is expected that many mines exposed to multiple-seam interactions will employ ARMPS-MSM to recognize hazardous conditions before an event occurs, and either avoid them or implement control strategies.

Outputs

9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Using Site Case Histories of Multiple Seam Coal Mining to Advance Mine Design Ellenberger-JL; Chase-FE; Mark-C; Heasley-KA; Marshall-JK In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :59-64	2003	Publication	Ground control
Collaborative Study of Multiple Seam Experience at Harris Mine Chase-FE; Worley-P; Mark-C Paper in Proc. 24th Intl. Conf. on Ground Control in Mining, West Virginia University, Morgantown, WV, 2005, pp. 79-85	2005	Publication	Ground control
Failure Mechanics of Multiple Seam Mining Interactions Zipf-RK In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :93-106	2005	Publication	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2006	Workshop, Seminar, or OIB	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2007	Workshop, Seminar, or OIB	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2008	Workshop, Seminar, or OIB	Ground control
Extreme Multiple Seam Mining in the US - SME Annual Meeting	2006	Publication	Ground control
Design for Predicating, Preventing, and Controlling Multiple Seam Interactions - 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Software Package: ARMPS-MSM (multiseam mining)	2006	Software	Ground control

Potential Intermediate Outcome for Ground Control

Design of Mine Ventilation Stoppings

Background

Stoppings play a key role in controlling ventilation throughout an underground mining complex. The law requires that they provide a minimum transverse load capacity (the force acting on the face of the stopping) of 39 pounds per square foot of area. This requirement is based on a freestanding analysis of the stopping, meaning that, by itself and without any restraint on the ends of the wall, the wall must be able to take pressure without failing. Investigators believe that this assumption inaccurately addresses the in-mine service load condition and as such, endangers mine workers by allowing structures with low transverse load



Failure of mine ventilation stopping from inadequate transverse load capacity

capacities to be employed anywhere in a mine. These stoppings are more prone to failure from pressure spikes caused by roof falls or ground pressures that squeeze the stoppings beyond their capacity. In addition, premature failures of stoppings pollute mine air with dangerous gases and dusts that can contribute to catastrophic explosions. If an explosion does occur, widespread damage to inadequately designed stoppings can make it more difficult to contain the fire. Efforts to reestablish ventilation can also put miners and rescue workers in danger following an explosion.

NIOSH is conducting research to show that arching is a more valid loading condition for stopping design and is working to develop a test protocol to evaluate the true loading capacity and limitations of block stoppings under arching conditions. Research to date has shown that transverse loading under arching conditions can be an order of magnitude higher than that considered in freestanding wall analysis and is directly dependent on block strength and wall geometry, not sealant properties. Since the current trend is toward the use of lightweight block materials to reduce the amount of physical strength required during construction (which in turn reduces handling injuries), it is imperative to understand that lower-strength, lightweight block materials will also significantly degrade the transverse load capacities of stoppings.

Potential Outcome

Proper design guidelines will ensure that stopping capacity matches the conditions in which they will be used in a mine. The impact of these guidelines will be to move the United States toward ratings for stoppings that are more indicative of their true transverse load capacity rather than one design for all applications as now permitted by mining law. Ultimately it is expected

that the mining law itself will be modified to recognize the design factors (currently ignored) needed to achieve a more appropriate design goal. Another future impact of this work will be the development of strain-softening materials that can preserve the transverse load capacity of the stopping at an acceptable level.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Numerical Modeling for Increased Understanding of the Behavior and Performance of Coal Mine Stoppings Burke-LM; Iannacchione-AT; Barczak-TM; Westman-EC In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining (August 3-5, 2004). Morgantown, WV: West Virginia University, 2004; :112-118	2004	Publication	Ground control
Load and Deflection Response of Ventilation Stoppings to Longwall Abutment Loading: A Case Study Oyler-DC; Hasenfus-G; Molinda-GM In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :34-41	2001	Publication	Ground control
Transverse Load Capacities of Dry-Stacked Block Mine Ventilation Stoppings Under Rigid Arching Loading Conditions - 11th U.S./North American Mine Ventilation Symposium, Penn State University, June 5-7, 2006	2006	Publication	Ground control
Evaluation of the Transverse Load Capacity of Block Stoppings for Mine Ventilation Controls (PhD dissertation)	2006	Publication	Ground control
Establishing More Appropriate Design Criteria for Mine Ventilation Stoppings - Annual SME Meeting, February 2007	2007	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Roof Span and Pillar Layout Guidelines for Stone Mines

Background

The room-and-pillar method is used in all operating underground stone mines in the United States. The dimensions of the pillars and roof spans in these mines are largely chosen on the basis of past experience without consideration of the local geological conditions that affect stability. A consequence is that unexpected rock falls from the roof and ribs of the workings can lead to injuries and fatalities among mine workers, and, in fact, have been the largest single cause of fatalities in underground stone mines over the past decade. This project will provide guidelines for roof spans and pillar layouts so that mine designers and operators can proactively design stable excavations to reduce the hazards associated with uncontrolled rock falls.



Pillar rib failure in a limestone mine

The project is being carried out using empirical methods in which case histories of stable and unstable mine workings (roof spans and pillars) in limestone mines in the eastern United States are evaluated to establish relationships between rock characteristics and stability. At each site, data on rock mass properties causes of instability, support techniques, and mining practices are being collected. These case histories will form a database for the development of design guidelines.

The case histories are being supplemented by numerical models and laboratory tests on rock samples from the mines to provide additional information on rock strength. The numerical modeling is being conducted to better understand the failure mechanics of pillars in hard, brittle rock and as part of the evaluation of the case studies.

Potential Outcome

The research will reduce the risk of rock falls in the more than 100 operating underground limestone mines. Project impacts will be achieved following 4 years of research by providing:

1. A methodology for assessing rock mass strength in underground stone mines based on current rock classification methods. In situ stress issues will also be addressed.
2. Design guidelines for pillar dimensions and pillar layouts based on local rock mass characteristics. Emphasis will be on slender pillars, which are more likely to be unstable than wider pillars.

3. Guidelines for designing stable roof spans to suit local rock mass and rock stress conditions.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Pillar Stability Issues Based on a Survey of Pillar Performance in Limestone Mines - International Conference on Ground Control in Mining	2006	Publication	Ground control
Proposed Design Procedures for Pillars in Limestone Mines - Mining Engineering (refereed journal)	2007	Publication	Ground control
Survey of Roof Stability in Limestone Mines - 2007 meeting of the Society for Mining, Metallurgy, and Exploration (SME)	2007	Publication	Ground control
Roof Stability Mechanics in Limestone Mines - 2007 U.S. Rock Mechanics Symposium	2007	Publication	Ground control
Design Procedures for Stable Roof Spans in Underground Limestone Mines - Mining Engineering (refereed journal)	2008	Publication	Ground control
Design Issues Related to the Strength of Slender Limestone Pillars - 2006 meeting of the Society for Mining, Metallurgy, and Exploration (SME)	2006	Publication	Ground control
Development of Design Guidelines for Stable Roof Spans in Limestone Mines - 2008 U.S. Rock Mechanics Symposium	2008	Publication	Ground control
Survey of Pillar Performance in Underground Limestone Mines - Open Industry Briefing (OIB) Underground Stone Safety Conference	2006	Workshop, Seminar, or OIB	Ground control

Potential Intermediate Outcome for Ground Control

Reducing Ground Fall Hazards in Coal Mines with Low Strength Roof

Background

Analysis of MSHA statistics indicates that mines accounting for just 20% of underground coal production were responsible for 60% of all roof falls reported to MSHA between 1995 and 2003. These mines are located primarily in the Illinois and northern Appalachian coal basins. Reducing the number and rate of ground falls at these mines is a major concern for MSHA and for the mine operators.



Ground fall in low-strength roof resulting from roof bolt failure

Underground coal miners face two significant hazards associated with falls of ground: roof collapse and flying pieces of rock. Both types of hazards are more likely when roof strength (uniaxial compressive strength, or UCS) is less than 5,000 psi and the Coal Mine Roof Rating (CMRR) value is less than 40. Unfortunately, many of the ground control safety technologies developed for the broad range of U.S. mining conditions, such as CMRR and the Analysis of Roof Bolt Systems (ARBS), tend to be less useful when applied to mines with extremely weak roof.

This 4-year project will begin in FY 2006, with Peabody Energy, Black Beauty Coal, RAG Coal, and Anker Energy expressing interest in collaborating with NIOSH. The research will

1. develop techniques for characterizing the strength and moisture sensitivity of weak roof,
2. suggest guidelines for panel orientation, length, and duration while considering the time-dependent strength of the roof,
3. develop methodologies for integrating supplemental and primary supports for maximum effectiveness, and
4. enhance the use of roof screens through ergonomic evaluations, machine modifications, economic evaluations, and educational and information transfer programs.

Potential Outcome

The project will culminate in a comprehensive set of design technologies for operating in weak roof while addressing exploration, mine layout, roof support, and rock fall prevention. Project results will be transferred to the mining community in a series of open-industry briefings. Implementation of these design technologies should result in a 50% reduction in the number of roof falls at the target mines, which will in turn reduce the overall number of roof falls in the United States by 30%. The enhanced use of roof screening should reduce the number of rock fall injuries by 25% nationwide.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Preventing Falls of Ground in Coal Mines With Exceptionally Low-Strength Roof: Two Case Studies Mark-C; Molinda-GM; Burke-LM In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proc 23rd Intl Conf on Ground Control in Mining, Morgantown, West Virginia, August 3-5, 2004. West Virginia University, 2004 Aug; :220-227	2004	Publication	Ground control
Make it Safer With Roof Screen NIOSH NIOSH 2004 Jan; :Video (VHS format)	2004	Video	Ground control; Surveillance and training; Traumatic injuries
Ground Control in Australian Weak Roof Mines - US-Canada Rock Mechanics Symposium, Vancouver, Canada	2007	Publication	Ground control
Effect of Time and Moisture on the Strength of Coal Measure Rocks - US-Canada Rock Mechanics Symposium, Vancouver, Canada	2007	Publication	Ground control
Application of the Personal Bolter Screen for Roof Control. 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Economic Analysis of Roof Screen Installation in the Underground Coal Mines. Annual Meeting of the American Society of Safety Engineers	2008	Publication	Ground control
Evaluation of Geophysical Techniques for Predicting Rock Strength from Boreholes - 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Numerical Modeling of Primary and Supplemental Support Interaction - SME Annual Meeting	2008	Publication	Ground control
Comprehensive Ground Control Design Methodology for Weak Roof - 28th International Conference on Ground Control in Mining	2009	Publication	Ground control
The Coal Mine Roof Rating (CMRR) - A Decade of Experience. J. of Coal Geology, in press	2006	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Highwall Mining Stability Guidelines

Background

Highwall mining is an important coal mining method in the United States and may account for approximately 4% of the total U.S. coal production. Highwall stability is the major ground-control-related safety concern in highwall mining. Studies have shown that three of the nine fatalities connected with auger and highwall mining in the last 20 years were caused by highwall collapse, and the only fatality in the last 5 years was due to highwall collapse. Thus, ensuring highwall stability through proper ground control engineering is of paramount importance to safe highwall mining operations.



Typical web and barrier pillar used in highwall mining

MSHA recognizes the safety concerns associated with highwall mining and requires each portable auger or highwall mining operation to develop and follow an appropriate highwall ground control plan that addresses web spacing and other measures necessary for safe recovery of the resource at high rates of recovery. A proper ground control plan for highwall mining should usually specify web pillar width, barrier pillar width, and number of holes between barriers given site-specific conditions, such as seam thickness, hole width, maximum hole depth, and maximum overburden depth.

Potential Outcome

To help mine operators address the new MSHA requirements, ground control researchers developed design charts and a new software package to specify required web and barrier pillar widths for highwall mining. The design charts have been reproduced in several publications and provide estimates of necessary web and barrier pillar widths. The highwall mining design software, available next year, has a form similar to the successful Analysis of Retreat Mining Pillar Stability (ARMPS) program and is named ARMPS-HWM (High Wall Mining). The interactive software package provides web and barrier pillar widths at given depths of cover and mining heights.

The design tools developed from the project will be widely distributed to stakeholders through classes at the MSHA Academy and open-industry briefings throughout the coal fields.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Analysis of Practical Ground Control Issues in Highwall Mining Zipf Jr-RK; Bhatt-SK In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV, August 3-5, 2004: West Virginia University, 2004 Aug; :210-219	2004	Publication	Ground control
Ground Control Design for Highwall Mining Zipf-RK 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, SME preprint 05-82. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-7	2005	Publication	Ground control
Analysis of Highwall Mining Stability - The Effect of Multiple Seams and Prior Auger Mining on Design Newman-D; Zipf-RK In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :208-217	2005	Publication	Ground control
Ground Control for Highwall Mining in the U.S. Zipf-RK; Mark-C International Journal of Surface Mining, Reclamation and Environment 19(3):188-217	2005	Publication	Ground control
ARMPS-HWM Software for Highwall Mining Design - Hands-on training workshop at the National Mine Safety and Health Academy, May 2006	2006	Workshop, Seminar, or OIB	Ground control
Software Package: ARMPS-MSM (multiseam mining)	2006	Software	Ground control

Potential Intermediate Outcome for Ground Control

Increase Roof Fall Forecast Times with Sensor-Based Monitoring Techniques

Background

Currently, miners have little, if any, warning of impending roof falls. NIOSH is in the process of deploying several monitoring systems at mines with known roof fall problems so that an extensive database of measurements of microseismic emissions, roof-to-floor convergence, and roof beam sag can be compiled. These mines have very diverse geologic conditions and stress regimes and are mined with different methods. Several years will be needed to collect enough data to prove or disprove adequately the validity and feasibility of this technology. Field sites will be added in the future to broaden NIOSH's database. This exhaustive scientific study will identify the precise trends capable of forecasting roof falls and define their limitations.



Monitoring rock failures and roof movement to warn of roof falls

The goals of this project are to:

1. Increase our fundamental knowledge of how roof falls behave,
2. Develop and evaluate sensor-based roof fall warning technology, and
3. Document the amount of time available to warn miners prior to a roof fall.

This research is aimed at increasing roof fall forecast times and location accuracy.

Potential Outcome

A sensor-based system composed of microseismic emission and roof beam deflection monitoring instruments has been developed. To date, this technology has successfully forecast events approximately 50 minutes ahead. Two field trials are currently underway.

Currently, all our research is being focused on the following research question: Can monitoring technology be used to increase the time between the recognition that a particular area of unstable roof rock is going to fall and the actual moment it begins to fall?

The research will be successful if it shows that a forecast window does exist and can be lengthened using a sensor-based monitoring system. Project results will then be formulated as guidelines for installing and using roof fall monitoring systems. With these systems, mine operators will be better able to identify those areas at high risk for roof falls and remove workers or take other corrective action before a roof fall occurs. The result will be to lower miner exposures to hazardous conditions and decrease roof fall injuries.

Outputs

13 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Forecasting Roof Falls with Monitoring Technologies - A Look at the Moonee Colliery Experience Iannacchione-AT; Bajpayee-TS; Edwards-JL In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :44-51	2005	Publication	Ground control
Characteristics of Mining-Induced Seismicity Associated with Roof Falls and Roof Caving Events Iannacchione-AT; Esterhuizen-GS; Bajpayee-TS; Swanson-PL; Chapman-MC Proceedings of the 40th U.S. Symposium on Rock Mechanics, ARMA/USRMS paper 05-678, Anchorage, AK, June 27-29, 2005; 10 pp	2005	Publication	Ground control
Characterizing Roof Fall Signatures from Underground Mines Iannacchione-AT; Burke-LM; Chapman-MC In: Proceedings of the Sixth International Symposium on Rockburst and Seismicity in Mines (Perth, Australia, March 9-11, 2005). Nedlands, Australia: Australian Centre for Geomechanics, 2005; :619-629	2005	Publication	Ground control
Relationship of Roof Movement and Strata-induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ Jr; Marshall-TE; Litsenberger-J Min Eng 56(12):53-60	2004	Publication	Ground control
Mapping Hazards with Microseismic Technology to Anticipate Roof Falls - A Case Study Iannacchione-AT; Batchler-T; Marshall-TE In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2004 Aug; pp. 327-333	2004	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control
100 Years of Improvement in Aggregate Worker Safety Iannacchione-A; Mucho-T Stone, Sand and Gravel Review 2003 Mar; :28-34	2003	Publication	Surveillance and training
An Examination of the Loyalhanna Limestone's Structural Features and their Impact on Mining and Ground Control Practices Iannacchione-AT; Coyle-PA In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :218-227	2002	Publication	Ground control
High Stress Mining Under Shallow Overburden in Underground U.S. Stone Mines Iannacchione-AT; Dolinar-DR; Mucho-TP In: Proceedings of the First International Seminar on Deep and High-Stress Mining. Nedlands, Australia: Australian Centre for Geomechanics, section 32, 2002 Nov; :1-11	2002	Publication	Ground control
Using Monitoring Technologies to Warn of Roof Fall Occurrences - SME Annual Meeting, St. Louis	2006	Publication	Ground control
Analysis of Microseismic data from the Burning Springs Mine. Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Analysis of Microseismic data from the Graymont Mine, The 26th International Ground Control Conference in Mining. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Develop Guidelines for Installing and Using a Sensor-Based Roof Fall Warning System. International Journal of Rock Mechanics and Mining Science	2008	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Reducing Ground Fall Hazards in Metal Mines with Weak Rock

Background

In the mid-1990's, the number of injuries from rock falls increased. This increase could be attributed to (1) an increase in new, inexperienced miners, who have shown to have a much higher rate of accidents than older, experienced miners, (2) an increase in the total number of underground workers, and (3) mining in weak rock surrounding the ore deposits, which resulted in an increase in rock falls.

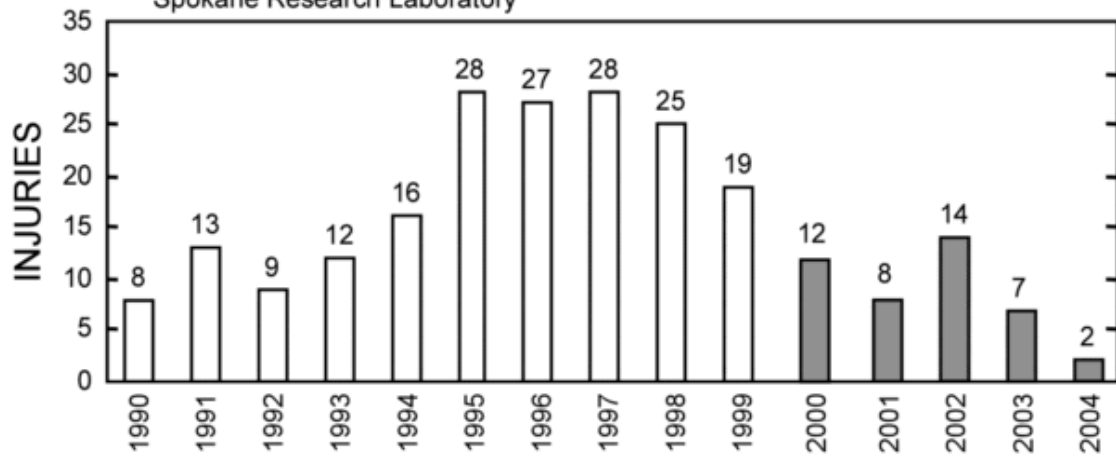
A research project was started in 2002 to develop tools to evaluate the relationship between geology, opening span, and support requirements. Thirty-four data collection points were established at eight mines in Nevada and four mines in Idaho and Montana. A manual of underground mine design for weak rock masses in hard-rock mines was developed. This manual contains information that relates span curves, rock mass rating (RMR) values, stope design curves, and equivalent linear overbreak/slough (ELOS) values and is used to select adequate support for the particular mining geology and selected opening span. It is being used by 75% of the active underground mines in Nevada and 50% of the underground mines in Montana and Idaho.

During 1999-2005, the mine design curves and applicable nomograms resulting from this research were transferred to the mining industry through 11 technical papers and 9 presentations. This research was also the focus of three workshops. A handbook was developed that is being used to design openings and select supports.

Potential Outcome

Since 2002, the critical information for mine design and the nomograms contained in the design manual have been adopted at most mines in Nevada, Idaho, and Montana. After these interventions began in 2002, ground fall injuries in Nevada mines have dropped, as shown in the bar graph. This injury reduction was due to the improved methods for the design of mine openings and selection of supports for metal mines with weak rock. Although many other factors must also be considered as contributors to this trend, the intervention by NIOSH was a factor for the reduction in ground fall injuries.

Injuries in Nevada, 1990-1999 (Hoch 2000), 2000-2004 appended by NIOSH
Spokane Research Laboratory



Outputs

9 Planned or completed outputs

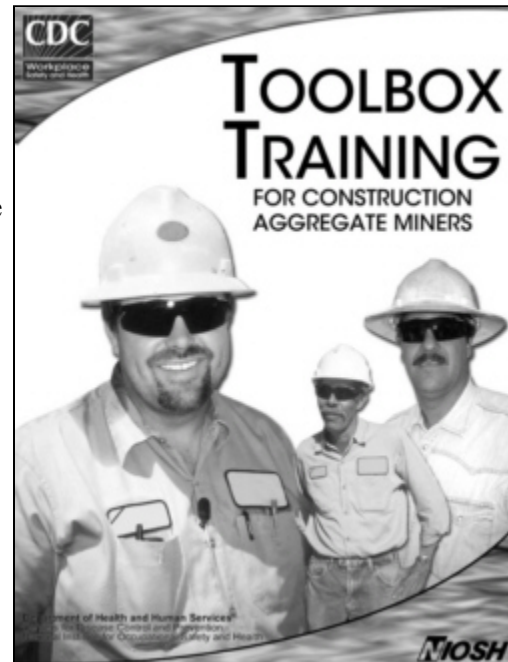
Title	Year	Output Type	Strategic Goal
Empirical Approaches for Weak Rock Mass Brady-T; Martin-L; Clark-L CIM Mining Industry Conference and Exhibition, Montreal, Quebec, Canada: Canadian Institute of Mining, Metallurgy, and Petroleum	2003	Publication	Ground control
UDEC Modeling of an Underground Opening in a Rock Mass of Varying Quality Lasich-TJ; MacLaughlin-MM; Brady-TM In: McLaughlin M, McNearney R, eds. Proceedings of the 39th Symposium on Engineering Geology and Geotechnical Engineering: Research to Practice (Butte, MT, May 18-19, 2004). Butte, MT: Montana Tech of the University of Montana, 2004	2004	Publication	Ground control
Tests of Fibre-Reinforced Shotcrete at the Chief Joseph Mine, Butte, Montana Martin-L; Dunford-J; MacLaughlin-M; Cronoble-R Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-20, 2005; :6 pp	2005	Publication	Ground control
Design in Weak Rock Masses: Nevada Underground Mining Operations Brady-T; Pakalnis-R; Clark-L Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-43, 2005; : 9 pp	2005	Publication	Ground control
Design Spans: Underhand Cut-and-Fill Mining Pakalnis R, Caceres C, Clapp K, Morin M, Brady T, Williams T, et al. Montreal, Quebec, Canada: Canadian Institute of Mining, Metallurgy, and Petroleum, pp. 1-9. [http://www.cim.org/meetings/techpapers/44/s44a2214p1883.pdf]	2005	Publication	Ground control
A Distinct Element Parametric Study of Failure Modes Around an Underground Opening in Rock Masses of Varying Quality MacLaughlin-MM; Pakalnis-R; Brady-TM American Rock Mechanics Association, 40th U.S. Symposium of Rock Mechanics, Anchorage, Alaska June 25-29, 2005, ARMA/USRMS 05-747	2005	Publication	Ground control
Update of Span Design Curve for Weak Rock Masses Ouchi-A; Pakalnis-R; Brady-T CIM Mining Industry Conference and Exhibition, Edmonton, Alberta, Canada, Canada Institute of Mining	2004	Publication	Ground control
Empirical Approaches for Opening Design in Weak Rock Masses Brady-T; Martin-L; Pakalnis-R Mining Technology (Transactions of the Institute for Mining and Metallurgy Section A), 2005, vol. 114, No. 1, March, 2005; :A13-A20	2005	Publication	Ground control
Influence of Intermediate Principle Stress on Rock Mass Quality Li-G; Vongpaisal-S; Pakalnis-R; Brady-T CAMI 2005 (Fifth International Conference on Computer Applications In Mineral Industries, November 1-3, 2005, Banff, Alberta, Canada	2005	Publication	Ground control

Potential Intermediate Outcome for Surveillance and Training

Improving Miner Safety by Developing Toolbox Training Sets

Background

Toolbox training, defined as short (usually 10- to 15-minute) weekly sessions conducted with work crews on site prior to work shifts, is a popular mode of worker occupational safety and health training used by field-based companies. Thousands of small U.S. mining companies do not have the number of employees nor the resources to warrant supporting even one on-site safety professional to identify hazards and apply relevant risk and prevention information. In particular, these small companies seldom possess the facilities or resources to provide their workers on-going training programs to address workplace safety and health. Many aggregate mines fit this small-company profile. In 2001, sand and gravel mines had a median of three employees per mine site in scattered locations that made training at centralized offices difficult. Between 1998 and 2002, the average fatality rate for sand and gravel miners was 31.1 per 100,000 FTE employees compared to 34.1 for coal, 21.3 for metal, 7.0 for nonmetal, and 17.8 for stone miners.



A set of 52 one-page toolbox training topics relevant to the aggregate industry was developed with input from health and safety specialists in the industry. In 2004, the toolbox training modules were requested by MSHA for inclusion in the Small Mines manuals. The manuals are meant for distribution to all small mines visited by MSHA's Small Mines Office personnel. Since ending the toolbox training research project, MSHA's Web page now includes a set of one-page toolbox training topics (<http://www.msha.gov/smallmineoffice/toolbox/tboxtalks.htm>) developed by the Small Mines Office.

Potential Outcome

Mines that operate in remote locations with limited work crews can significantly raise the health and safety awareness of their employees by using these short training modules. The modules are available online for downloading from the NIOSH publications and mining Websites. The format of the training includes hazard identification, best practices, accident stories, and directed discussion among the work group to encourage sharing experiences and site-specific information. Preliminary evaluations of the effectiveness of this type of adult learning indicate that this training format is more effective for young miners, who are an increasing portion of the workforce as baby boomers retire. A large segment of the aggregate industry is expected to adopt toolbox training methods by 2010, making future reductions in occupational injuries and illnesses likely.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Evaluating Toolbox Training for Construction and Mining: Sand and Gravel Boldt-CMK Workshop at the National Holmes Safety Association Conference, San Antonio, TX, Jun. 6-7, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Developing Toolbox Training Materials for Mining Varley-FD; Boldt-CMK In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :39-44	2002	Publication	Surveillance and training; Traumatic injuries
Developing Toolbox Training for Aggregate Miners Boldt-CMK Workshop at the Western TRAM Conference, Reno, NV, June 16-20, 2003	2003	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Toolbox Training For Construction Aggregate Miners Boldt-CMK US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2004-162; 2004 Aug: 1-108	2004	Publication	Surveillance and training; Traumatic injuries
Evaluating Toolbox Training for Construction and Mining Boldt-CMK NIOSH OIB, 107th annual meeting of Northwest Mining Association meeting, Dec. 2, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries

Potential Intermediate Outcome for Surveillance and Training

Improving Miner Safety by Developing Interactive Computer Simulation Training

Background

Mining is a dangerous occupation, and while disasters are not common, miners need to know what to do when the unthinkable happens. It is not generally possible nor legal for them to receive first-hand experience of disasters in a training format, however. The Virtual Reality Miner Safety Training (VRMST) format allows trainees to operate in a simulated disaster without actually being exposed to the inherent dangers. Preliminary evaluations show that this is an effective way to get and keep the interest of trainees and expose them to learning without harm.



Computers allow development of innovative miner training

Potential Outcome

The VRMST software is designed to allow mine safety professionals to augment traditional miner safety training with state-of-the-art computer simulations. The broad adoption of this new training technology enables safety trainers to provide an experiential learning environment for mine workers rather than traditional classroom training.

Outputs

8 Planned or completed outputs

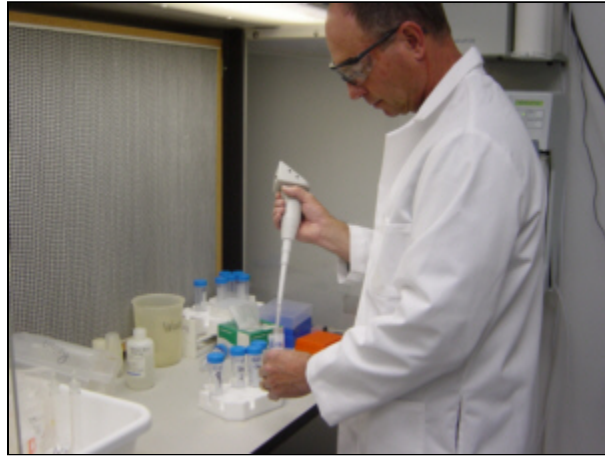
Title	Year	Output Type	Strategic Goal
Computerized Accident Reconstruction and Training for Metal/Non-Metal Mines Filigenzi-MT; Orr-TJ; Ruff-TM Am J Ind Med, 1999 Sep 36(S1):116-118	1999	Publication	Surveillance and training
Hazard Recognition Computer Based Simulation Orr-TJ; Filigenzi-MT; Ruff-TM In: Jenkins FM, Langton J, McCarter MK, and Rowe B, eds. Proceedings: Thirtieth Annual Institute on Mining Health, Safety, and Research (Salt Lake City, UT, Aug. 8-11, 1999). Blacksburg, VA: Department of Mining and Minerals Engineering, Virginia Polytechnical Institute, 2001 Aug; :21-28	2001	Publication	Surveillance and training
Virtual Reality for Mine Safety Training Filigenzi-MT; Orr-TJ; Ruff-TM Applied Occupational and Environmental Hygiene, vol. 15, no. 6, 2000; :465-469	2000	Publication	Surveillance and training
Mine Escapeway Multiuser Training with Desktop Virtual Reality Orr-TJ; Girard-JM In: Bandopadhyay S, ed. Application of Computers and Operations Research in the Mineral Industry: Proceedings of the 30th International Symposium (APCOM 2002) (Phoenix, AZ, Feb. 25-27, 2002). Littleton, CO: Society of Mining, Metallurgy, and Exploration	2002	Publication	Surveillance and training
Annual International Workshop on VR Mining Applications and Collaboration (held in conjunction with another mining-related annual meeting)	2007	Workshop, Seminar, or OIB	Mine disasters
Evaluation of the VR and CBT Map Reading Training, Journal of Safety Research	2006	Publication	Mine disasters
Guidelines and Seminars: implementing CBT and VR mine safety training	2007	Workshop, Seminar, or OIB	Mine disasters
Evaluation of the VR Mine Evacuation Training Module, International Journal of Emergency Management	2009	Publication	Mine disasters

Potential Intermediate Outcome for Surveillance and Training

Improving the Accuracy of Determining Worker Exposure to Airborne Silver

Background

Currently, analytical methods to determine silver in workplace air samples measure total silver, which includes both the soluble and insoluble species. A method has not been available to differentiate between total silver and the more toxic soluble silver compounds. Both insoluble (i.e., metallic) and small amounts of soluble silver (i.e., silver nitrate) can be found in smelters and refineries; however, the metallic fraction is not considered a health risk. The current MSHA permissible exposure limit (PEL) for an 8-hour shift is 10 $\mu\text{g}/\text{m}^3$ total silver (adopted from the American Conference of Governmental Industrial Hygienists' [ACGIH] 1973 Threshold Limit Values [TLV's]). However, in 1981, ACGIH changed the TLV's to 10 $\mu\text{g}/\text{m}^3$ for soluble silver compounds and 100 $\mu\text{g}/\text{m}^3$ for insoluble silver compounds. This research served to validate a method for determining water-soluble silver in workplace air samples.



Analysis of samples in the laboratory

The results of this research have been published and were presented at the Fifth International Symposium on Modern Principles of Air Monitoring. The organizing committee invited NIOSH to present a summary of this method for measuring soluble silver at its annual symposium held in Loen, Norway, in June 2005.

Potential Outcome

Improving the methodology for delineating the presence of different species of airborne silver will provide more accurate measures of worker exposures to its most harmful forms. MSHA and mine and mill operators can now concentrate their efforts on protecting workers from soluble silver compounds. The Health Division of MSHA's Metal and Nonmetal Safety and Health program has been contacted to discuss reassessing the MSHA PEL for silver within the next few years.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Exposure-Related Health Effects of Silver and Silver Compounds: A Review Drake-PL; Hazelwood-KJ The Annals of Occupational Hygiene, Vol. 49, No. 7; :575-585	2005	Publication	Surveillance and training
Soluble Silver Method - Peer-reviewed paper in the Journal of Environmental Monitoring. Expected publication date - January 2006	2006	Publication	Surveillance and training
Soluble Silver Method, NIOSH Manual of Analytical Methods	2007	Publication	Surveillance and training

Potential Intermediate Outcome for Surveillance and Training

New Miner Training

Background

The U.S. coal mining industry will face a critical shortage of workers within the next five years as the majority of the present mine workers reach retirement age. At the same time, America's need for coal will increase. To mine this coal, the industry will have to turn to a young, inexperienced workforce.

Unfortunately, young inexperienced workers are injured at a much higher rate than are older workers who, presumably, have more experience. This trend has been repeatedly documented during the past 20 years. A 1982 National Academy of Sciences study of 15 large coal companies found a very marked

correlation between age and disabling injury rates among underground coal miners. A worker between the ages of 18 and 24 was about three times more likely to be injured than was a miner 45 years or older. A similar pattern was observed in 2002 study using MSHA injury data and Bureau of Labor Statistics estimate of ages. To break this pattern, the new cohort of workers will need to be better trained and exposed to large sets of proficiencies, key ones being good technical skills matched with judgment and decision-making skills. NIOSH personnel are assisting United Mine Workers Career Centers, Inc., in developing a pilot project to establish an apprentice training center to service the southwestern Pennsylvania/northern West Virginia coal fields. This innovative project will not only provide an efficient means of developing a trained workforce, but will also create career opportunities for workers displaced from other industries. Once completed, this pilot can then serve as a model throughout U.S. coal fields.



A key industry need is effective integration of new miners

Potential Outcome

By 2009, the apprentice miner training program will provide insights into a variety of important topics associated with the recruitment, training, and retention of young people for the mining industry. Recommendations can be made regarding (1) strategies for improving the methods and materials used to train new miners, (2) strategies for facilitating the transfer of vocational training to the job, and (3) methods for assessing students' competency at performing critical mining tasks. The program will also influence the use of new technologies for delivering training. Just as important, a company hiring one of the program's graduates would acquire a highly trained person with proven work habits who could quickly become a productive miner. The likelihood of injury would be significantly reduced for this worker, thus keeping compensation costs down. A more productive miner with a better chance of going home safe at the end of the shift is both socially and economically beneficial.

Outputs

4 Planned or completed outputs

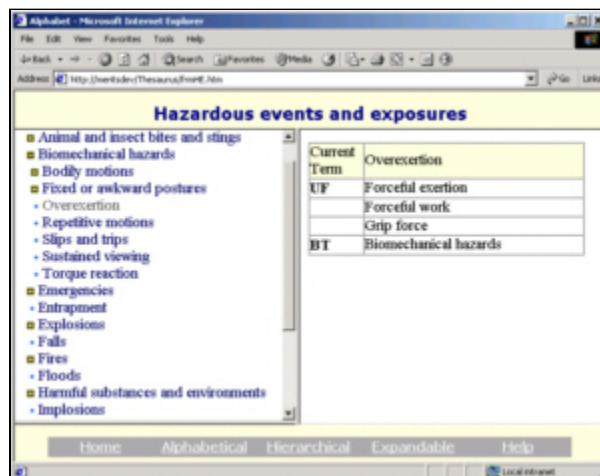
Title	Year	Output Type	Strategic Goal
The use of new technologies to train new miners	2007	Training	Surveillance and training
How well do new miners perform critical mining tasks? - Journal of Safety Research	2008	Publication	Surveillance and training
Guidelines for a new miner curriculum	2008	Video	Surveillance and training
A training intervention to instill a safety and health value in young/inexperienced underground coal miners - Safety Science	2010	Publication	Surveillance and training

Potential Intermediate Outcome for Surveillance and Training

Improved Technology Transfer Via the Web

Background

The Internet is an efficient and cost-effective resource for disseminating public information. However, as the amount of Internet content increases, it's increasingly difficult to find information. Reducing the complexity of locating information is a high priority research area. For example, the World Wide Web Consortium (W3C) envisions a future "Semantic Web" (<http://www.w3.org/2001/sw/>) where information can be processed by automated tools as well as humans. Towards that goal, new web technologies are being developed and combined with knowledge management and artificial intelligence techniques. Many technologies can be used now to improve searches on individual web sites or portals. For example, effective indexing of content is crucial to information discovery. ANSI/NISO/ISO standards specify how to track metadata ("information about information") for web resources, and a W3C Recommendation (Resource Description Framework) specifies how to exchange that knowledge on the Web.



The Mining Safety and Health Thesaurus - terms related to "Hazardous events and exposures"

This effort focuses on improving the dissemination of safety and health information on the NIOSH Mining web site. Methods will be researched and developed for indexing content based on emerging standards. Techniques such as "faceted navigation" will be implemented to leverage this metadata to improve access to web content. One project deliverable will be a faceted, hierarchical thesaurus of indexing terms compiled by content experts. This thesaurus will have potential use beyond the NIOSH Mining web site. Additionally, the techniques developed for this project could serve as a common indexing structure that allows organizations to share safety and health information.

Potential Outcome

One outcome of this research will be a better organized and highly indexed web site of mining safety and health information for our stakeholders. For example, users will be able to explore content in a hierarchical and faceted manner, with multiple paths leading to the same content (e.g. the ability to browse by hazard, target audience, date of publication, or format of the web content). Users of the new web site will experience an increase in ease of use and accuracy when searching for specific information. This, in turn, will increase the knowledge transfer of the latest NIOSH Mining research results and products to our stakeholders. Instant and accurate access to this wealth of information via the web will allow them to immediately apply it in their work place and improve mine worker health and safety.

In addition, if the "Semantic Web" is realized, this research will have an even greater impact. The NIOSH Mining web site will be in a position to participate in the next phase of the Internet, where semantic search engines will target information much more precisely. This would significantly improve NIOSH's ability to disseminate information as well as provide a template for other safety and health organizations to follow.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Advanced website for mining information	2006	Software	Surveillance and training
NIOSH Mining Safety and Health Thesaurus Users Manual (Glowacki, Unger) - NIOSH numbered publication	2007	Publication	Surveillance and training
Development of a Taxonomy for Indexing Web-based Mining Safety and Health Research (Glowacki, Unger) - Journal of Digital Information (peer-reviewed)	2007	Publication	Surveillance and training
A Taxonomy-based Navigation System for Mining Safety and Health Research (Unger, Glowacki) - APCOM 2007 (Santiago, Chile)	2007	Publication	Surveillance and training
Improving Access to Mining Safety and Health Information (Glowacki, Unger) - SME Annual Meeting	2007	Publication	Surveillance and training